RECONNAISSANCE REPORT

Old Greenwich

Greenwich, Connecticut

HURRICANE AND STORM DAMAGE REDUCTION STUDY

AUGUST 1994

US Army Corps
of Engineers
New England Division

HURRICANE AND STORM DAMAGE REDUCTION STUDY

OLD GREENWICH
GREENWICH, CONNECTICUT

RECONNAISSANCE REPORT

AUGUST 1994

NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149

OLD GREENWICH
GREENWICH, CONNECTICUT
SHORE PROTECTION AND FLOOD DAMAGE REDUCTION STUDY
RECONNAISSANCE REPORT

EXECUTIVE SUMMARY

This reconnaissance scope study was conducted under the special continuing authority contained in Section 103 of the 1962 River and Harbor Act, as amended. It investigated alternative measures to reduce recurring storm damages and coastal flooding to the Old Greenwich area in Greenwich, Connecticut.

Greenwich is located in southern Fairfield County, in southwestern Connecticut. The town is a predominantly residential community located on Long Island Sound, 30 miles northeast of New York City and 46 miles southwest of New Haven, Connecticut. The study area included a total of 124 residential structures with first floor elevations below the 100-year flood level in Old Greenwich.

In Old Greenwich, the west side fronts Greenwich Cove and is somewhat protected by Greenwich Point. Flooding is mainly due to storm surge above the stillwater level in this part of town. The east side of Old Greenwich fronts Long Island Sound and is subjected to flooding that is associated with high tides and wave action during severe storms and hurricanes. Portions of this coastline are protected by privately-owned seawalls. The most recent storm of December 1992 caused damages of about $1,500,000 in the study area.

This report describes the plan formulation process that resulted in the selection of a plan for hurricane and storm damage reduction. The selected plan involves the raising of the first floor of 124 houses above the 100-year frequency flood elevation. All structures with first floor elevations less than one foot above the 100-year flood level would be raised in accordance with applicable FEMA and NFIP regulations. The estimated first cost of this plan is $5,137,000 with an annual cost of $419,900. Total annual benefits associated with raising 124 structures are estimated at $439,600. The project is therefore economically justified with a benefit to cost ratio of 1.05 to 1.

However, the town of Greenwich has decided to further review participation in a cost shared feasibility study. Therefore, further Corps of Engineers study in this area was terminated.

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INTRODUCTION

Recent severe coastal flooding has caused damage to residential properties along the shoreline of Old Greenwich. It is estimated that the storm during the winter of 1992 caused about $1,500,000 in damages in the study area. This study focuses on measures to reduce future damaging effects of wave and tidal action on properties that are located within the 100-year flood plain.

This report presents the results of a study conducted to determine the feasibility of providing shoreline and flood protection to the Old Greenwich section of Greenwich. The study was conducted at the request of the Town of Greenwich in their letter of May 19, 1993.

STUDY AUTHORITY

This report was prepared under the special continuing authority contained in Section 103 of the 1962 River and Harbor Act, as amended. This authority allows for the construction of economically justified hurricane and storm damage reduction projects, provided that a financially capable and legally empowered local sponsor agrees to cost share in project construction and maintain and operate the project upon completion. Coastal projects constructed under the Section 103 authority are cost shared between the Federal government and a non-Federal sponsor, with the Federal share being 65 percent of the total cost, not to exceed $2,000,000, which includes all project related costs for study report preparation, design, and construction.

STUDY PURPOSE AND SCOPE

The purpose of this study is to determine whether further planning to alleviate storm and flood damages in the study area merits Federal involvement.

This study focused on storm damage reduction to properties that are located within the 100-year flood plain in Old Greenwich (see Plate 1 and 2). Alternative plans were examined in sufficient detail to conduct a cost-benefit analysis. Environmental resources in the study area were discussed and environmental impacts of the proposed plan assessed.

PRIOR STUDIES AND REPORTS

Flood Plain Information - Byram River, Greenwich, Connecticut, Report and Technical Appendix (October 1964)

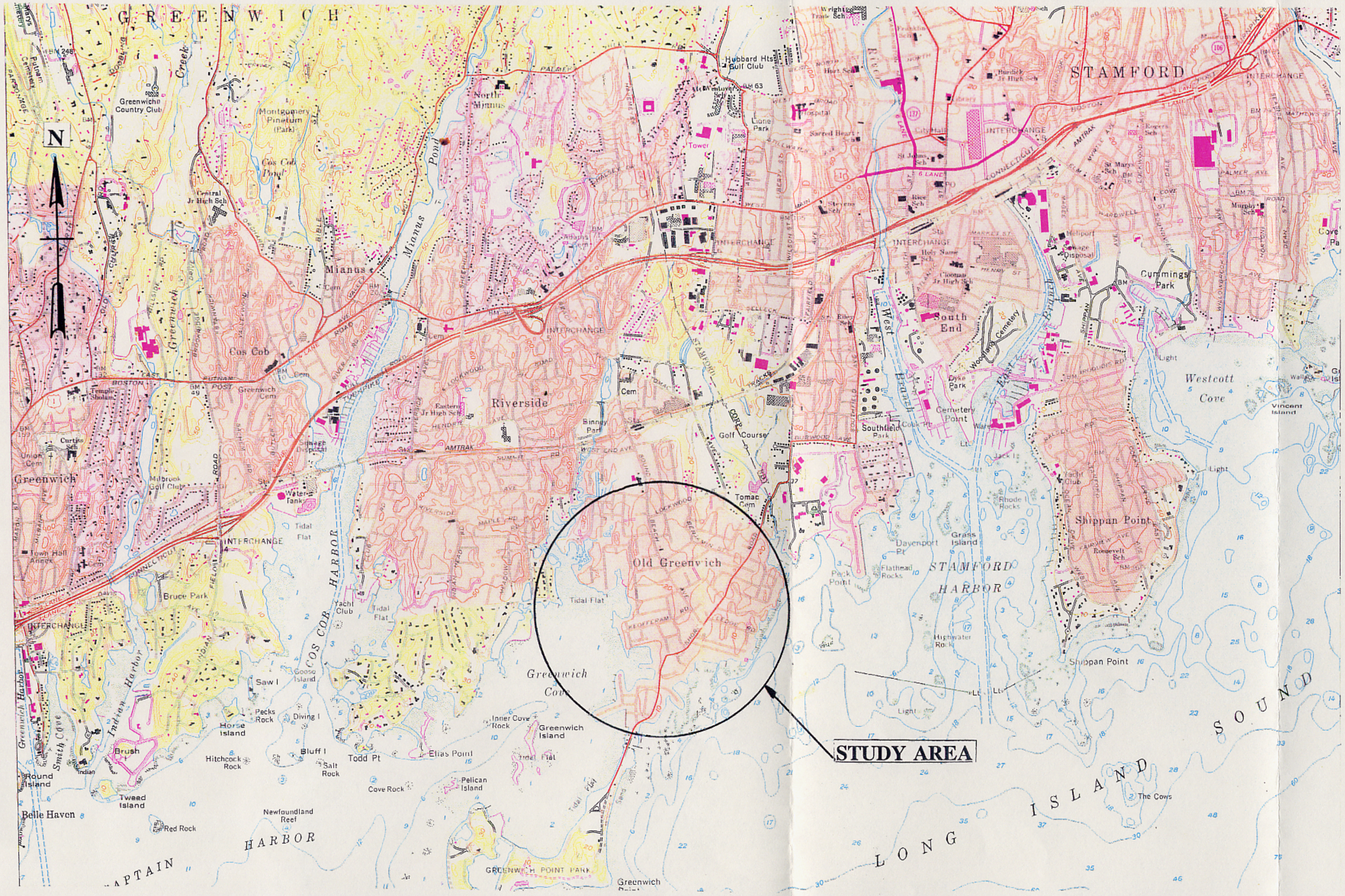
At the request of the Town of Greenwich, a flood plain information report was prepared by the Corps of Engineers for the Byram River from the NYNH&H railroad bridge to about a mile above the Merritt Parkway. This report is intended to assist the town in establishing flood plain regulations and to aid property owners in weighing the advisability of further development in the flood plain. The report was prepared for wider public dissemination, both to create a general awareness of the continuing flood problem along the Byram River and to help insure that future development in the flood plain will be made with the knowledge of the potential flood risks and hazards.

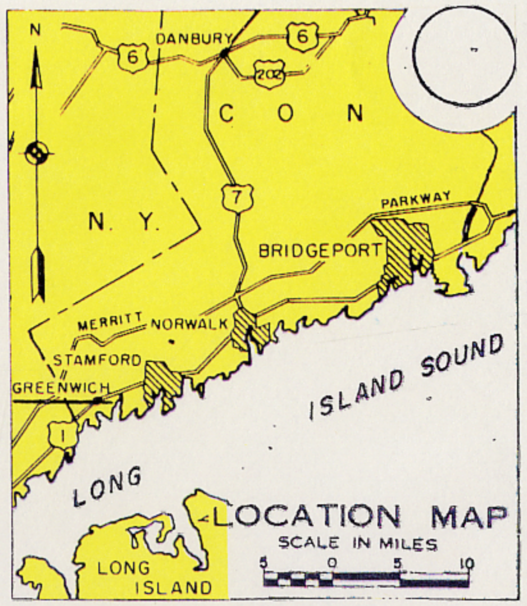
Flood Insurance Study, Town of Greenwich, Connecticut (August 1986)

This study by the Federal Emergency Management Agency investigates the existence and severity of flood hazards in the Town of Greenwich, Fairfield County, Connecticut, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

Northeaster of December 1992 - High Water Marks, Central and Western Connecticut (April 1994)

This report documents the locations and elevations of 135 high water marks recorded after the Northeaster of December 1992 which impacted the coast of New England from December 11-14, 1992. These high water marks were obtained at various locations along the shoreline from Greenwich, Connecticut to Old Lyme, Connecticut. Photographs, location maps and written descriptions for each high water mark are also included in this report. The report





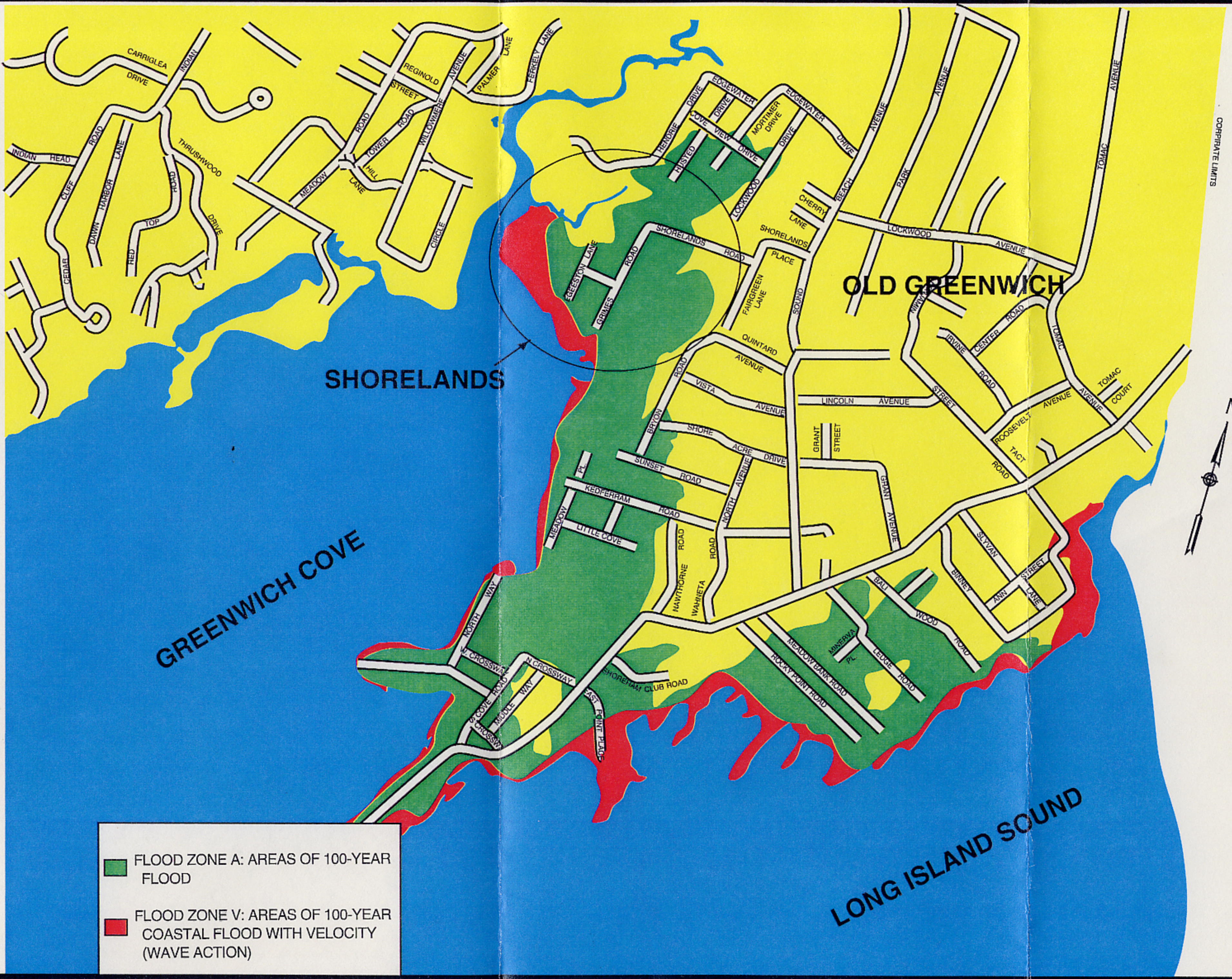
SHORE PROTECTION & FLOOD DAMAGE REDUCTION

LOCATION MAP

OLD GREENWICH
GREENWICH, CONNECTICUT

US Army Corps of Engineers
New England Division

PLATE 1



SHORE POTECTION & FLOOD DAMAGE REDUCTION

100 YEAR FLOOD PLAIN

OLD GREENWICH
GREENWICH, CONNECTICUT

US Army Corps of Engineers
New England Division

PLATE 2

was performed under Section 206 of the Flood Control Act of 1960 (PL 86-645).

EXISTING CONDITIONS

STUDY AREA DESCRIPTION

The Town of Greenwich is located in southern Fairfield County, in southwestern Connecticut (Plate 1). It is the extreme southwesterly town in Connecticut. The town is bounded on the west by the Town of Rye, New York which includes the village of Port Chester; on the west and north by the Town of North Castle, New York which includes the villages of Armonk and Banksville; on the east by the Town of Stamford, Connecticut, and on the south by Long Island Sound. Greenwich is a predominantly residential community located on Long Island Sound, 30 miles northeast of New York City and 46 miles southwest of New Haven, Connecticut. The study area consists of a total of 163 residential structures that are located within the 100-year flood plain of Old Greenwich. Old Greenwich is situated in the eastern portion of Greenwich. It is bordered by the Long Island Sound on the east, and Greenwich Cove on the west.

The west side of the Old Greenwich subdivision fronts Greenwich Cove and is somewhat protected by Greenwich Point, a dogleg peninsula. Flooding occurs mainly due to storm surge above the stillwater level on low lying areas of this part of Old Greenwich. The east side of Old Greenwich fronts Long Island Sound and is subjected to flooding that is associated with high tides and wave action during severe storms and hurricanes. However, portions of this coastline are protected by privately-owned seawalls.

PHYSICAL SETTING

The Shorelands, a private residential area, is located on the western portion of Old Greenwich (see Plate 2). It is a private residential area surrounded by earthen dikes in sections, varying in elevation from 7.0 to 10.6 feet, NGVD. The interior of the Shorelands is relatively low with ground elevations from 6 to 12.6 feet, NGVD. The remaining portions of the study area along the coastline are generally protected by privately-owned seawalls. The elevations of these seawalls range from 11 to 15 feet NGVD. Many of these structures have been built by individuals or private groups and detailed information concerning them is not available.

A generalized subsurface profile at Greenwich Cove appears to be topsoil underlain by a thin, discontinuous layer of till, and shallow bedrock. The till is an inhomogeneous, clayey to sandy, fine to coarse gravel with cobbles and boulders. The underlying bedrock is typically a light to dark gray, medium grained, foliated gneiss. Occasional bedrock outcrops were observed to occur in the study area. Surficial beach deposits, consisting of gray, fine to medium sand, with lesser amounts of gray, organic silt and peat, overlie the typical soil profile in the tidal areas of the cove. Most of the beaches in the study area are the "pocket" type, formed between two projecting rocky headlands. Marsh deposits (organic silt and peat) may be present along former bedrock channels. Granular fill material has been imported into the cove area to construct homes, roads, dikes and walls.

ENVIRONMENTAL SETTING AND RESOURCES

Part of Old Greenwich is built upon filled areas which were once saltmarsh or mudflat. Saltmarsh is still presented along much of the Greenwich Cove shoreline. Extensive intertidal mudflats are found in Greenwich Cove and along the eastern shoreline to a lesser extent. Mudflats provide excellent shellfish and shorebird habitat. Commercial shellfishing was banned by legislation years ago in Greenwich Cove. Recreational shellfishing is permitted along the causeway between Old Greenwich and Greenwich Point and between Greenwich Point and Sand (Pelican) Island except during the summer months. Recreational fishing for bluefish and striped bass occurs along Greenwich Point.

Most of Old Greenwich is developed as a residential community. Commercial development is limited, and there is no significant industry. Greenwich has a population of 58,441 according to the 1990 U.S. Census data. The average household income is $65,072. Home values typically range between 600,000 and 800,000 dollars. There are no known prehistoric or historic archaeological resources in the proposed project area. A prehistoric site located north of the Shorelands area was reportedly mostly destroyed. Two additional prehistoric sites are located south of the study area in Greenwich Point Park.

A more thorough discussion of environmental resources in the study area and the environmental effects of potential flood control measures is presented in Appendix C.

TIDAL FLOOD HISTORY

Tidal flooding within the study area is caused primarily by hurricanes or extratropical storms. Hurricanes are tropical in nature and are characterized by low barometric pressures of 29.0 inches or less and maximum wind speeds in excess of 75 miles per hour. In the northern hemisphere, hurricanes consist of winds revolving in a counter-clockwise direction around a calm center or "eye". Their diameter can vary considerably, from as small as 50 miles across to over 500 miles wide. Winds at the outer edge are usually light and increase in intensity as they approach the center. Hurricanes that have had the most severe affect on the study area usually approach from the south after curving east of Florida and skirting the middle Atlantic states.

Coastal storms in New England occur most frequently during the fall, winter and spring months. Most coastal storms develop in the southeastern or mid Atlantic regions of the country. Although the winds and surges accompanying the storms are not as great as hurricanes, they do pose a constant threat to coastal communities. "Northeasters" are coastal storms which pass to the east or south of Long Island and result in strong east or northeast winds within the Sound. Severe northeasters produce abnormal high tides that are above damage stages in most communities.

Hurricanes

Hurricane of September 21, 1938 Tidal flooding from this hurricane was the greatest ever experienced in Long Island Sound. The center of the hurricane entered Connecticut about 15 miles east of New Haven and proceeded northwesterly at a forward speed of 50 to 60 miles per hour. The Hurricane caused extreme high tides throughout most of the Sound, with a tidal surge of about seven feet above the normal predicted tide at Bridgeport. Wave action accompanying the storm produced a devastating effect upon the shoreline, resulting in widespread damages. Wave heights ranged from ten feet at New London to 15 feet at New Haven and Bridgeport.

Hurricane of September 14, 1944 In this event, the eye of the storm passed inland just west of Pt. Judith, Rhode Island and continued in a northeasterly direction at a forward speed of 30 to 35 mph veering out to sea at Boston, Massachusetts. The hurricane tide arrived in the Sound at about mean tide at the eastern end and about two hours after predicted high tide at the western end, which resulted in moderately high ocean levels.

The maximum gust was an estimated 104 mph at Hartford, Connecticut. A one-minute wind of 99 mph and a five-minute velocity of 81 mph were recorded at New York City. The lowest pressure of 28.30 inches was recorded at Westerly, Rhode Island.

Hurricane of August 31, 1954 (Carol) The second most damaging hurricane to strike southern New England occurred just 16 years after the record 1938 event. The center of this storm crossed the shoreline of Connecticut near New London with a forward speed of about 45 mph and then followed a general northerly path across New England. As the hurricane surge occurred at or near predicted normal high tide within the Sound, tide levels rose to near record heights. Tidal surges ranged from five to eight feet higher than normal tides.

The wind attained a maximum gust of 135 mph and a five minute sustained velocity of 98 mph at Block Island, Rhode Island. Minimum pressures of 28.2 and 28.3 inches were recorded at Storrs and New London, Connecticut.

Damages from flooding of low shore areas occurred throughout Connecticut as a result of extremely high tides. Waves were particularly damaging east of the Connecticut River. Statewide damages occurred as a result of inundation of commercial and residential properties. Coastal losses included damage to fishing and pleasure craft, harbor facilities, shorefront residences and bathing beach establishments.

Hurricane of September 27, 1985 (Gloria) Hurricane Gloria made landfall in Westport, after crossing Long Island. The "eye" of the hurricane, then continued on its north-northeastward track, passing near Hartford before exiting the state at Suffield. Wind gusts of hurricane force ripped through the southern and central, as well as the eastern portion of the state, with the peak gust for the entire state recorded at 92 mph at Bridgeport. The lowest sea level pressure was 28.50 inches, recorded at Bridgeport. Other peak wind gusts included 82 mph at Hartford, 75 mph at New Haven, and 66 mph at Windsor Locks. Along the coast, up to 20,000 people were evacuated from their homes from Greenwich to Stonington and hundreds of small craft were torn from their moorings, damaged or sunk. Five docks were ripped up in Milford Harbor and about one hundred pleasure craft were torn from their moorings. However, coastal flooding was at a minimum despite tides of 2 to 4 feet above normal, since Gloria reached the coast near low tide.

Coastal Storms

Coastal Storm of November 25-26, 1950 The storm of 25 November 1950 started as a disturbance from Virginia, intensified rapidly and moved north-northeastward reaching New England on the 25th, resulting in the most violent storm of its kind on record. Tidal flooding was experienced along the entire Connecticut coast and was particularly severe west of New Haven. The two crests of severe tidal flooding, approximately equal in height, occurred on two successive tide cycles. At New Haven, the recorded maximum one-minute sustained wind velocity and gust were 55 and 77 miles per hour, while corresponding velocities at Hartford were 70 and 100 mph. The strong gale wind velocities were of longer duration than in the 1938 and 1944 hurricanes. Although the lower limit of hurricane wind velocity was exceeded, it was not classified as a hurricane since it was not of tropical origin.

Coastal Storm of November 6-7, 1953 This storm commenced when a low pressure area off the Georgia coast moved rapidly up the Atlantic seaboard, developed into a major storm and brought rain, snow and high winds to northeastern United States. The crest of most severe tidal flooding occurred coincident with the first predicted high tide at most locations on the Sound. Maximum wind gusts at Block Island, Rhode Island were 98 mph. Although the entire New England coast was affected to some degree by this storm, damage was heaviest along the Connecticut shore of Long Island Sound.

Coastal Storm of October 14-16, 1955 The storm resulted when an intense low pressure system moved northward from Florida and stalled off the New Jersey coast for three days. In addition to the gale force winds and unusually heavy rains (6 to 12 inches), the storm caused severe tidal flooding at the western and central parts of the Sound. There were five consecutive damaging high tides in which surges ranging from 2 to 5 feet were experienced.

Coastal Storm of December 11-14, 1992 The Northeaster of December 1992 brought record snowfall to parts of interior New England and major flooding to much of the coast. The storm originated from a surface low pressure system over Georgia on Thursday, December 10. In the central United States a trough formed across the Ohio Valley and southern Appalachians. Meanwhile, a strong surface high pressure remained centered on Maine. This combination of events established a strong easterly gradient north of the surface low with storm force winds over the ocean south of New England. Peak gusts in Bridgeport were recorded at 46 knots. The Town of Greenwich experienced significant flooding and damages during this storm. In the

Byram Harbor area, flooding occurred from inlets and rivers first where the storm surge caused backwater and flooding from the inland. In Old Greenwich and Greenwich Point Park, high waves flooded streets, caused structural damage to seawalls and homes, and closed roads that were covered with sand and rocks.

TIDAL FLOOD PROBLEM

Throughout history, tidal floods produced by hurricanes and extratropical storms have caused loss of life, massive damage to public and private property and in some instances significant ecological destruction along the Connecticut shoreline. In addition to high water levels, waves generated by wind associated with severe storms have also caused serious damage to the coastline. Although wave measurements or statistical wave data is very limited in the study area, waves generated by southwesterly to southeasterly winds pose the greatest threat to the study area. Since wave height is dependent upon wind speed and fetch distance, winds from southerly directions result in a much greater threat due to the relatively long fetch available in Long Island Sound.

PROBLEM IDENTIFICATION

WITHOUT PROJECT CONDITION

The without project condition represents those conditions which are likely to occur without any Federal flood damage reduction measures. Old Greenwich's exposure to severe storms from the east and northeast will continue to cause damage to properties, buildings and seawalls along the coast and the cove portion of Old Greenwich. In the absence of flood control improvements, either structural or non-structural, periodic flooding events along Long Island Sound will continue to inundate the study area and threaten the health and safety of the residents. Recurring floods will cause more rapid deterioration of structures and a general lowering of property values, unless high maintenance and repair costs are expended to prevent this deterioration. Expected annual damages for the without project condition in Old Greenwich are estimated at $530,800. An assessment of expected flood damages is contained in Appendix B - Economic Analysis.

PLANNING OBJECTIVES

Water resources planning undertaken by Federal agencies is directed by the Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. These principles provide the basis for Federal participation with river basin commissions, State agencies and other concerned groups in developing plans for the use of water and related land resources to meet short and long term needs. The Federal objective of such studies is to contribute to national economic development (NED), consistent with protecting the Nation's environment, pursuant to environmental statues and applicable executive orders and Federal planning requirements. Plans were developed in the interest of achieving the general objectives of enhancing national economic development and protecting environmental quality. National economic development is enhanced by increasing the value of the nation's output of goods and services, and by improving national economic efficiency.

Based on an assessment of the problems and needs of the study areas and the goals of the non-Federal sponsor, the study has concentrated on the following planning objectives:

* Reduce potential tidal flood damages in Old Greenwich.

* Preserve or enhance the environmental resources of coastal floodplain areas.

STUDY AND PLANNING CRITERIA

Recommendations to proceed to the next study stage (feasibility phase) are guided by two general constraints:

* Information be sufficiently detailed to determine that at least one potential solution will likely have Federal interest and be in accord with current policies and budgetary priorities; and

* The potential solution be supported by the non-Federal (local) sponsor, and be consistent with their policies and statutes on coastal zone management, flood plain management and flood control. Since this study focused on flood damage reduction, Federal interest was established if a potential solution was economically justified and the local sponsor demonstrated support for further study.

PLAN FORMULATION

Systematic consideration of the problems, needs and opportunities in the study area led to the formulation of alternative plans for reconnaissance level evaluation. These plans were formulated to reduce flood damages in Old Greenwich and to achieve the planning objectives stated previously. Two plans for local flood protection were investigated in sufficient detail to determine their economic and engineering feasibility.

SCREENING OF ALTERNATIVES

Dikes/Seawalls

In the "Shorelands" area, perimeter or ring dikes could be constructed to limit the impact of storm surges above the stillwater level in this low lying area. A long perimeter dike (approximately 4,000 linear feet) with approximately 500 linear feet of concrete flood walls construction and at least two tidal gate structures would be required. Smaller ring dikes could be constructed around only the groups of homes that have flood problems. Each ring dike would require at least one gate structure. However, due to the relative length of the dikes compared to the number and type of structures being protected in this area, dike construction was judged to be not cost efficient. In addition, construction of perimeter dikes and floodwalls would result in loss of substantial saltmarsh and mudflat habitat. Connecticut has placed a high priority on protecting the state's remaining intertidal habitat, and such losses would not be acceptable to permitting agencies.

The eastern side of Old Greenwich, which fronts Long Island Sound, is protected by privately-owned seawalls to some degree. These seawalls are found in various locations and in various heights ranging from 11 to 15 feet NGVD along the coast. Raising or replacing the existing seawalls could reduce the amount of overland flooding considerably. However, these seawalls may not be constructed to Corps of Engineers design standards, and would most likely require removal and reconstruction in accordance with Corps specifications. Proper drainage, including pumping stations and gravity outlets, would also be required to prevent ponding of interior storm runoff. Therefore, this option was found to be prohibitive due to the excessive cost. In addition, structural solutions along the coast in the state of Connecticut are generally found to be unfavorable by regulatory and resource agencies.

House Raising

The option of house raising within the 100 year flood plain of Old Greenwich was also evaluated. By raising the first floor elevation of existing residential structures above the 100 year frequency flood level, damage from recurring floods to the structure or contents therein would be minimized. This plan would maintain the continuity of the neighborhood and ease the fears of its residents.

Selected Plan

The selection of a plan, to be recommended for implementation, is based on its effectiveness, economic efficiency, environmental considerations and public acceptance. After careful consideration of these factors, the selected plan was determined to be the raising of 124 houses above the 100 year flood level. This is economically viable and the least environmentally damaging plan and will reduce future flood damages in Old Greenwich. Unfortunately, raising first floor elevations would have an adverse aesthetic impact on many structures. Severity of the impact would depend on the height the home needed to be elevated, home style and footprint. Construction activities would also have some temporary, adverse impacts on the local quality of life. Noise, dust, and truck traffic would disturb the community while work is underway. However, plans would strive to minimize these impacts as much as possible.

DESCRIPTION OF SELECTED PLAN

There are a total of 124 houses with first floor elevations below the 100-year flood elevation within the study area. The selected plan is to raise the first floor of these 124 residential structures above the 100 year frequency flood level. First floor elevations were approximated using a two-foot contour map provided by the Town of Greenwich and a hand level. Using data from the hydrologic and hydraulic analysis and FEMA Flood Insurance Rate Maps, the 100-year flood zone elevations were determined for the study area. A 100-year flood elevation of 12 feet NGVD was used for the Grimes Rd., Eggleston La., Meadowland La., Oak La. and the Old Clubhouse Rd. in the Shoreland area. It was also used for the streets including Mortimer St., Heusted Rd., Bryon Rd., Sunset Rd., Meadow Pl., Kedferram Rd., and Ledge Rd. In the remaining portion of Old Greenwich along the shoreline, a 100-year flood elevation of 13 feet NGVD was used. These areas included Little Cove Rd., Shore Rd., East Point La., Shoreham Club Rd., West Way, North Way Rd., West Crossway, Cove Rd., North Crossway, Rocky Point Rd., and Meadowbank Rd (see Plate 2). The complete hydrologic and hydraulic analysis is attached to this report as Appendix A.

Structures within the study area were classified into three different types. Type A is defined as a one- or two-story timber structure with a footprint of less than 1,000 square feet, having one masonry chimney, a concrete foundation, and no attached garage. Type B contains the same features as Type A except that the footprint for a Type B structure is greater than 1,000 square feet or that the structure has an odd or complex shape. Type C contains one- or two-story timber structures with a footprint greater than 1,000 square feet or with an odd or complex shape, more than one chimney, or an attached garage. Several structures were noted as being very large (footprint greater than 2,000 square feet), having all masonry construction, or of historical significance. Although costs for these structures may be significantly higher, the number of these houses is low (less than 5%) and were therefore considered to be Type C structures.

All of the structures are considered to be in the flood zone A as defined by the Flood Insurance Rate Maps. According to FEMA, these structures must be raised such that all non floodproof material is raised above the 100-year flood elevation. In order to keep the bottom of the timber floor joists above the flood elevation, all houses with first floor elevations less than one foot above the 100-year flood level are required to be raised. In addition, all houses will be elevated in accordance with all applicable FEMA and NFIP regulations. Table 1 summarizes the structure types and the number of structures with first floors below the 100 year frequency flood events.

It is currently estimated that the total project first cost for raising 124 houses in Old Greenwich would be $5,137,000. Table 2 provides the components that are included in this cost estimate.

ECONOMIC ANALYSIS

In examining the economic justification of the house raising alternative, the annual benefit of the plan must exceed its annual cost. The annual benefit for each structure was determined by raising the first floor elevations to above the 100 year flood level, and recalculating the

TABLE 1

STRUCTURES IN THE FLOOD PLAIN

Street Name	100-Year Flood El.	Structure Type A	Structure Type B	Structure Type C	Total
Grimes Road	12 feet	10	5	6	21
Eggleston Lane	12 feet	--	--	2	2
Meadowland Lane	12 feet	--	--	--	0
Oak Lane	12 feet	--	1	--	1
Old Clubhouse Road	12 feet	--	--	--	0
Mortimer Street	12 feet	2	6	--	8
Heusted Road	12 feet	--	3	2	5
Bryon Road	12 feet	--	4	3	7
Sunset Road	12 feet	--	2	1	3
Meadow Place	12 feet	1	2	4	7
Kedferram Road	12 feet	1	3	1	5
Ledge Road	12 feet	--	1	2	3
Little Cove Road	13 feet	--	--	5	5
Shore Road	13 feet	--	--	2	2
East Point Lane	13 feet	--	2	1	3
Shoreham Club Rd	13 feet	--	1	--	1
West Way	13 feet	--	2	13	15
North Way Road	13 feet	--	--	7	7
West Crossway	13 feet	--	--	4	4
Cove Road	13 feet	--	2	3	5
North Crossway	13 feet	--	1	4	5
Rocky Point Road	13 feet	--	--	5	5
Meadowbank Road	13 feet	--	6	4	10
TOTAL		14	41	69	124

TABLE 2

SUMMARY OF PROJECT COSTS

Construction Cost (1994 Price Level)	
Raise 124 Houses	$4,777,000
Total Construction Cost	$4,777,000
Project First Cost	
Planning, Engineering & Design (PED)	$ 182,000
Construction Management	$ 178,000
Total Project First Cost	$5,137,000*
Project Cost Share	
Total Federal Cost (Federal cap of $2,000,000 minus preconstruction study cost of $208,000)	$1,792,000
Non-Federal Cost ($5,137,000 - $1,792,000)	$3,345,000

*** Cost estimate to raise 124 homes. Feasibility study detailed evaluation is expected to significantly reduce this figure.**

expected annual damages. The expected annual damages in the study area remaining after project implementation were subtracted from the existing annual damages to determine the annual benefit. Costs were estimated for each type of structure based on other Corps of Engineers studies and adjusted for this specific area. Annual costs were developed using a project economic life of 50 years and the current interest rate of 8%. The benefit to Cost Ratio was then calculated to determine if the project was economically justified and eligible for federal participation. Costs and benefits of this plan was developed based on providing protection from a 1 percent (100 year) annual chance flood event. A comparison of project benefit and cost is made in Table 3. Annual benefit is $439,600 and annual cost is $419,900, for a benefit cost ratio of 1.05 and net annual benefit of 19,700.

TABLE 3

PROJECT JUSTIFICATION

Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit/Cost Ratio	Net Annual Benefits
124	$5,137,000	$419,900	$439,600	1.05	$19,700

CONCLUSIONS

The coastal flooding problem in Old Greenwich has been studied, and alternatives to alleviate this problem have been formulated. Based upon reconnaissance level engineering, economic studies, the project plan of raising residential properties in Old Greenwich will reduce future flood losses. This plan involves raising the first floors of the homes above the 100 year flood elevation. Approximately 124 houses indicate economic justification for further study as a result of the reconnaissance level investigation. In reality, many houses which fall in the Type C category and/or have first floor elevations that are close to the 100-year frequency flood level, would most likely be screened out in the next study phase due to lack of economic justification. The Type C structures have very large and complex shapes, some of these houses are all masonry construction with historical values. Therefore, the level of difficulty for raising would be increased, and the costs for raising would be significantly higher. Additionally, if the first floor elevation of any structure is close to the 100-year flood elevation, the expected damages of these homes would be less and their chances for justification would be lower.

For this reconnaissance level study, economic justification of a project was based on grouping houses considered as potential candidates for raising. Annual benefits and annual costs are determined from the group of houses as a whole to determine whether there is any Federal interest for further study. In this case, the reconnaissance study demonstrated a positive plan for raising the 124 houses in the study area.

The study findings and results were presented and discussed with the Greenwich town officials and residents at a meeting held on November 9, 1994. The town of Greenwich has decided to further review participation in a cost shared feasibility study. This review is expected to be completed in late 1995. Therefore, further Federal study in this area is not warranted at this time.

ACKNOWLEDGMENT

This report was prepared under the supervision and management of the following New England Division personnel:

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Ms. Rose Schmidt - Geotechnical Engineering
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Ms. Jenny Tan - Civil Engineering
Mr. John Yen - Cost Engineering
Ms. Karen Umbrell - Economic Analysis
Mr. Marc Paiva - Historic Properties
Mr. Mike Penko - Environmental Considerations

Special thanks are extended to the Department of Public Works, Engineering Division of the Town of Greenwich.

APPENDIX A

HYDRAULIC ANALYSIS
OLD GREENWICH
GREENWICH, CONNECTICUT

BY
ENVIRONMENTAL ENGINEERING & HYDRAULICS BRANCH
WATER CONTROL DIVISION
ENGINEERING DIRECTORATE

DEPARTMENT OF THE ARMY
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HYDRAULIC ANALYSIS
OLD GREENWICH
GREENWICH, CONNECTICUT

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HYDRAULIC ANALYSIS
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1. PURPOSE

This report presents results of studies concerning coastal flooding conditions at Old Greenwich, Greenwich, Connecticut. The report addresses tidal flooding under existing conditions for use in evaluating protective measures, including raising homes. The study, performed under Section 103 Authority, shows considerable flooding occurs in Old Greenwich under existing conditions.

2. DESCRIPTION

Greenwich is a predominantly residential community, located in southern Fairfield County, in southwestern Connecticut (see plate 1). The study area focuses on Old Greenwich, located in the eastern portion of Greenwich (see plate 2). Old Greenwich is bordered on one side by Greenwich Cove, and by Long Island Sound on the other. While the cove portion of Old Greenwich is somewhat protected by Greenwich Point, the east side is open to Long Island Sound and subject to flooding and wave damage. Portions of Old Greenwich have some form of shoreline protection. The Shorelands, a private residential area, is surrounded by earthen dikes in sections, varying in elevation from 7.0 to 10.6 feet, NGVD. The interior of the Shorelands is relatively low with ground elevations from 6 to 12.6 feet, NGVD. Other portions of the coast are protected by privately-owned seawalls.

3. TIDAL HYDROLOGY

a. Astronomical Tides. In the study area, tides are semidiurnal, with two high and two low waters occurring each lunar day (approximately 24 hours, 50 minutes). The resulting tide range is constantly varying in response to relative positions of the earth, moon, and sun, with the moon having the primary tide producing effect. Maximum tide ranges occur when orbital cycles of these bodies are in phase. A complete sequence of tide ranges, repeated over an approximate interval of 19 years, is known as a tidal epoch. Because of continual variation in water level due to tides, several reference planes, called tidal datums, have been defined to serve as reference points for measuring elevations of both land and water. The most recent epoch for which the National Ocean Survey (NOS) has published tidal datum information is 1960 - 1978. Tidal datums are referenced to the National Geodetic Vertical Datum of 1929 and revised periodically to account for relative sea level rise, a phenomenon observed through tide gaging and tidal benchmark measurements along most of the U.S. coast. At the NOS tide gage in Bridgeport Harbor, the rise has been observed to be slightly less than 0.1 foot per decade.

Tidal datum information for Greenwich, shown in table 1 and plate 3, was estimated based on Bridgeport data, to represent conditions at the study area. At Greenwich, the mean range and mean spring range of tides are 7.2 and 8.3 feet, respectively. However, maximum and minimum predicted astronomic tide ranges are about 12.0 and 2.9 feet, respectively. These were estimated by applying probability factors given in CERC Special Report 7 (Harris, 1981) for Bridgeport Harbor to the subordinate station at Greenwich.

TABLE 1

GREENWICH COVE
TIDAL DATUM PLANES
ESTIMATED USING BRIDGEPORT NATIONAL OCEAN SURVEY TIDE GAGE
(Based Upon 1960-78 NOS Tidal Epoch)

	Tide Level (ft, NGVD)
Maximum Predicted Astronomical High Water	6.8
Mean Spring High Water (MHWS)	4.9
Mean High Water (MHW)	4.3
Minimum Predicted Astronomical High Water	2.0
Mean Tide Level (MTL)	0.7
National Geodetic Vertical Datum (NGVD)	0.0
Maximum Predicted Astronomical Low Water	-0.9
Mean Low Water (MLW)	-2.9
Mean Spring Low Water (MSLW)	-3.5
Minimum Predicted Astronomical Low Water	-5.2

b. Storm Types. Two distinct types of storms, distinguished primarily by their place of origin as being either extratropical or tropical cyclones, influence coastal water levels and waves, and must be recognized in studying New England coastal problems.

(1) Extratropical Cyclones. These are the most frequently occurring variety of cyclones in New England. Low pressure centers frequently form or intensify along the boundary between a cold, dry continental air mass and a warm, moist marine air mass just off the coast of Georgia or the Carolinas, and move northeastward more or less parallel to the coast. These storms derive energy from temperature contrast between cold and warm air masses. Organized circulation patterns associated with this type of storm may extend for 1,000 to 1,500 miles from the storm center. The wind field in an extratropical cyclone is generally asymmetric with the highest winds in the northeastern quadrant. When the storm center passes parallel to, and to the southeast of, the New England coastline, and highest onshore windspeeds are

from the northeast, these storms are called "northeasters" or "nor'easters" by New Englanders. As the storm approaches and passes, local wind directions may vary from southeast to slightly northwest. Coastlines exposed to these winds can experience high waves and extreme storm surge. Such storms cause frequent tidal flooding along the Connecticut coastline. Other storms, taking a more inland track, can have high winds from the southeast and are referred to as "southeasters." The prime season for severe extratropical storms in New England is November through April.

(2) Tropical Cyclones. These storms form in a warm moist air mass over the Caribbean and waters adjacent to the West Coast of Africa. The air mass is nearly uniform in all directions from the storm center. Energy for the storm is provided by the latent heat of condensation. When maximum windspeed in a tropical cyclone exceeds 75 mph, it is labeled a hurricane. Wind velocity at any position can be estimated, based upon the distance from the storm center and forward speed of the storm. The organized wind field usually does not extend more than 300 to 500 miles from the storm center. Recent hurricanes affecting New England generally have crossed Long Island Sound and proceeded landward in a generally northerly direction. However, hurricane tracks can be erratic. The storms lose much of their strength after landfall. For this reason, the southern coast of New England experiences the greatest hurricane surge and wave action from strong southerly to easterly winds. Hurricanes have been a principal cause of major tidal flooding in the Long Island Sound area. The hurricane and tropical storm season in New England generally extends from August through October.

c. Winds. An estimate of windspeed is one of the essential parameters in determining design wave heights, which are used in computations to analyze how much runup from breaking waves will overtop a beach or coastal structure. Height and periods of waves are limited by windspeed and duration, the distance over which the wind blows (fetch) and the distance over which the wave travels. Driven by hurricane winds, breaking waves will run up on a beach or overtop vertical structures well above the actual stillwater height. The rise of water level due to a storm can amount to only 1 or 2 feet in the open ocean, while its magnitude can reach 6 to 10 feet or more at coastal points.

Wave information at near shore locations are determined by simulating the generation of waves in open water and routing them shoreward. Since maintenance of wave gages near coasts during storms is both difficult and costly, near shore wave estimates are usually based on available meteorological data such as wave "hindcasts" provided by the Waterways Experiment Station (WES) Wave Information Studies (WIS).

Wave height and period are estimated based on windspeed, duration,and fetch distance. Ideally, windspeed and direction data actually recorded on Long Island Sound would be used to estimate locally generated waves. However, in the absence of data from Long Island Sound, land-based data may be used.

The National Weather Service (NWS) recorded 13 years of hourly one-minute average windspeed and direction data, from 1949 to 1974, at Igor I. Sikorsky Memorial Airport in Stratford, Connecticut. This is the land-based coastal meteorological station, nearest to the study area, where complete wind data are available. The Water Resources Investigation Study entitled: "Tidal Flood Management, West-Central Connecticut" (NED, 1988) contains an analysis of data recorded at Sikorsky Memorial Airport.

In order to condense the wind data into useable form, hourly 1-minute average windspeed data were adjusted to a standard 33-foot observation height, and 1-minute average windspeeds were converted to 1-hour average windspeeds. From this 1-hour average wind data, shown in table 2, percent occurrence of wind direction and windspeed range was computed, with results shown in table 3.

d. Storm Tides. The total effect of astronomical tide combined with storm surges produced by wind, wave, and atmospheric pressure contributions is reflected in actual tide gage measurements. Since the astronomical tide is so variable at the study area, occurrence time of the storm surge greatly affects the magnitude of the resulting tidal flood. Obviously, a storm surge occurring at a low astronomical tide would not produce as high a water level as one occurring at a higher tide. Also, the storm surge itself varies with time, thus introducing another variable into the makeup of the total flood tide.

As established from development of the Standard Project Hurricane for southern New England, the faster moving hurricanes (30 knots and greater) produce higher wind velocities in Long Island Sound (a one knot velocity is equivalent to 1.15 miles per hour). Although 50 or 60-knot storms can produce the highest wind velocities, the storm travels so rapidly that it tends to run ahead of the tidal surge. This tendency would have less effect on surge buildup than with the 40-knot storm, which has a larger radii of maximum winds, and was, therefore, selected as a basis for critical conditions and calculation of surge heights at all communities within the Sound. Calculations showed that the 40-knot storm, with large radii of maximum winds, would cause the greatest surge portions of Long Island Sound.

Location of the storm track, relative to a coastal community, influences the magnitude of the storm's effect. As hurricanes and other low pressure systems in the northern hemisphere rotate

TABLE 2

STRATFORD, CONNECTICUT
ADJUSTED HOURLY WIND OBSERVATIONS BETWEEN "ENE" AND "NW"
(One-Hour Average Values)

Percent of Onshore Windspeed and Direction Observations (X 10)

Direction	0-5	5-10	10-15	15-20	20-25	25-30	Over 30	All Inclusive	Average Speed	Maximum Speed
	Windspeed Range (MPH)									
ENE	10	18	27	10	5	2	0	73	9.5	41.9
E	10	19	28	9	5	2	1	74	9.6	47.5
ESE	7	15	16	4	2	0	0	45	9.3	36.9
SE	8	14	11	2	0	0	0	36	7.9	38.9
SSE	8	14	10	2	0	0	0	34	7.7	26.6
S	12	23	22	5	2	1	0	65	8.8	38.9
SSW	9	21	28	8	3	0	0	70	9.7	37.9
SW	16	39	55	12	4	1	0	126	9.3	32.8
WSW	13	39	49	13	5	1	0	120	9.7	44.1
W	14	36	46	14	8	2	1	120	9.4	36.3
WNW	13	27	44	17	11	4	1	117	10.2	36.3
NW	19	26	41	19	12	3	1	121	10.0	34.5
ENE-NW	139	291	377	115	57	16	4	1,000	9.3	47.5

NOTE: Windspeed ranges indicated include values greater than the lower limit and less than or equal to the higher limit

TABLE 2

STRATFORD, CONNECTICUT
ADJUSTED HOURLY WIND OBSERVATIONS BETWEEN "ENE" AND "NW"
(One-Hour Average Values)

Percent of Onshore Windspeed and Direction Observations (X 10)

	Windspeed Range (MPH)									
Direction	0-5	5-10	10-15	15-20	20-25	25-30	Over 30	All Inclusive	Average Speed	Maximum Speed
ENE	10	18	27	10	5	2	0	73	9.5	41.9
E	10	19	28	9	5	2	1	74	9.6	47.5
ESE	7	15	16	4	2	0	0	45	9.3	36.9
SE	8	14	11	2	0	0	0	36	7.9	38.9
SSE	8	14	10	2	0	0	0	34	7.7	26.6
S	12	23	22	5	2	1	0	65	8.8	38.9
SSW	9	21	28	8	3	0	0	70	9.7	37.9
SW	16	39	55	12	4	1	0	126	9.3	32.8
WSW	13	39	49	13	5	1	0	120	9.7	44.1
W	14	36	46	14	8	2	1	120	9.4	36.3
WNW	13	27	44	17	11	4	1	117	10.2	36.3
NW	19	26	41	19	12	3	1	121	10.0	34.5
ENE-NW	139	291	377	115	57	16	4	1,000	9.3	47.5

NOTE: Windspeed ranges indicated include values greater than the lower limit and less than or equal to the higher limit

Table 3

FREQUENCY OF ADJUSTED ANNUAL MAXIMUM WIND SPEEDS (MPH)
STRATFORD, CONNECTICUT

(Based on 13 Years of Hourly Observations, 1949-1974)

Direction: ENE

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	24	33	41	46	52	58	64
1	19	27	33	37	42	47	52
3	18	24	27	29	32	35	37
8	16	22	24	25	26	27	28

Direction: E

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	25	36	46	52	60	67	74
1	20	29	37	42	48	54	60
3	17	26	33	38	45	50	55
8	15	22	29	33	40	46	52

Direction: ESE

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	22	31	36	41	46	51	56
1	18	25	29	33	37	41	45
3	13	21	24	26	27	28	29
8	13	19	22	24	27	29	31

Direction: SE

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	19	27	36	41	48	55	62
1	15	22	29	33	39	44	50
3	12	18	21	22	23	24	25
8	7	15	18	19	20	20	21

Table 3, cont.

FREQUENCY OF ADJUSTED ANNUAL MAXIMUM WIND SPEEDS (MPH)
STRATFORD, CONNECTICUT

(Based on 13 Years of Hourly Observations, 1949-1974)

Direction: SSE

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	18	30	32	33	34	35	35
1	15	24	26	27	28	28	28
3	14	20	23	26	29	31	34
8	7	16	18	20	22	23	24

Direction: S

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	23	35	40	44	48	51	54
1	19	28	33	35	39	41	44
3	18	25	28	30	32	34	36
8	5	20	24	26	28	29	30

Direction: SSW

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	24	34	40	44	48	52	55
1	19	28	32	35	39	42	45
3	18	23	25	27	29	30	32
8	15	19	23	27	32	36	40

Direction: SW

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	22	32	37	39	42	45	47
1	18	26	30	32	34	36	38
3	18	22	26	30	35	39	43
8	13	20	23	24	26	27	29

Table 3, cont.

FREQUENCY OF ADJUSTED ANNUAL MAXIMUM WIND SPEEDS (MPH)
STRATFORD, CONNECTICUT

(Based on 13 Years of Hourly Observations, 1949-1974)

Direction: WSW

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	17	35	45	51	59	65	71
1	14	29	36	41	47	52	57
3	15	24	30	34	40	44	48
8	13	22	27	29	33	36	38

Direction: W

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	19	35	41	44	47	49	52
1	15	29	33	35	38	40	42
3	12	26	30	31	33	34	35
8	10	22	25	27	28	29	30

Direction: WNW

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	24	36	41	43	46	49	51
1	19	29	33	35	38	39	41
3	17	26	29	30	32	33	34
8	15	22	25	27	29	30	31

Direction: NW

Duration (hours)	Expected Return Period (Years) 1	2	5	10	25	50	100
1 min	22	35	40	42	45	47	50
1	18	28	32	34	37	38	40
3	16	24	27	29	31	33	35
8	16	21	24	26	28	30	32

in a counterclockwise direction, the winds will be highest and southerly, in a particular community, if the east side of the storm track passes directly over it.

On the west side of the storm center, the counterclockwise rotation of the storm produces northerly winds, which are generally in opposition to the storm movement. The resultant wind velocities are subtractive and usually smaller than those experienced on the east side. On the east side of the storm track, components affecting a surge consist of forward speed of the storm, high circulating hurricane winds, and low barometric pressure, and are additive. Such conditions may cause abnormally high tides and waves that are often intensified at the heads of coves and bays.

e. Tide-Stage Frequency. Tidal flood profiles for the coast between Willets Point, New York and Westport, Connecticut, estimated from the trend in normal tides and historic 1944, 1954, and 1938 high watermarks, are shown in plates 4 and 5. The estimated frequency of tidal flooding at Greenwich Cove, derived from the tidal flood profiles, is shown in plate 6 and summarized in table 4.

TABLE 4

ESTIMATED FREQUENCY
OF TIDE STAGES AT
GREENWICH COVE, GREENWICH, CONNECTICUT

Frequency (years)	Stillwater Tide Elevation (ft, NGVD)
100	11.7
50	11.2
25	10.4
10	9.5
5	8.7
2	7.5

4. TIDAL HYDRAULICS

a. Standard Project Hurricane. The Standard Project Hurricane (SPH) is representative of the most severe combination of meteorological conditions that are considered reasonably characteristic of the region. It is based on the history and analysis of hurricanes in the Narragansett Bay and Long Island Sound areas.

The maximum SPH tidal elevation of 13.2 feet at Bridgeport Harbor was determined in 1941 by adding the design surge of 9.0 feet to a mean spring high water elevation of 4.2 feet NGVD. The maximum SPH tidal elevation at Greenwich Cove is 15.2 feet NGVD, as interpolated on the New England Coastline Tidal Flooding Survey plate C-3, September 1988.

b. Wave Growth. As part of the reconnaissance effort for Greenwich, wave heights and periods were computed for wave runup and overtopping analyses. Design wave heights were calculated for different portions of Old Greenwich, using the Automated Coastal Engineering System (ACES), version 1.07.

This required determining a predominant wind direction and whether wave generation is fetch, duration, or depth limited. The shallow water and fetch restricted options were chosen for the portion of Old Greenwich inside Greenwich Cove, including the Shorelands. Fetch lengths within the cove are less than 1 mile. The only fetch direction extending outside the cove into Long Island Sound is southwest. This fetch is approximately 15 miles long at an average depth of 15 feet. Deep water and fetch restricted options were chosen for the section of Old Greenwich open to Long Island Sound. Open water fetch lengths radiate from 20 miles east-southeast to 8.9 miles south-southwest, and depth of water in Long Island Sound typically exceeds 40 feet.

(1) Wind Direction. Aces was used in an initial analysis to compare wave heights and periods generated by winds from various directions. The adjusted 8-hour duration, 100 year windspeed previously analyzed from National Weather Service data at Sikorsky Memorial Airport (Tidal Flood Management, West-Central Connecticut, NED 1988) were entered into ACES. The only direction yielding wave generation inside Greenwich Cove was southwest; therefore, results generated from wind from this direction were considered as best representing storm-induced tidal flooding along Greenwich Cove. Results from wind blowing from the ESE direction were considered best for the back section of Old Greenwich, along Long Island Sound.

(2) Design Wave Heights and Periods. Inside Greenwich Cove, design wave heights and periods for waves generated by winds sustained from the southwest direction for a duration of 8 hours were determined for return periods of 100, 50, 25, 10, and 5 years. The SW windspeeds, corresponding to these return periods, are 29, 27, 26, 24 and 23 miles per hour, respectively. Design wave heights and periods are shown in table 5.

TABLE 5

WIND GENERATED WAVES
INTERIOR, GREENWICH COVE
GREENWICH, CONNECTICUT

Period (years)	SWL (ft,NGVD)	Duration (hours)	Speed (mph)	Height (ft)	Period (sec)	By
100	11.7	8	29	2.3	3.0	Fetch
50	11.2	8	27	2.2	2.9	Fetch
25	10.4	8	26	2.1	2.8	Fetch
10	9.5	8	24	1.9	2.7	Fetch
5	8.7	8	23	1.8	2.7	Fetch

Assumptions:

Winds from southwest
Shallow water wave generation
Restricted fetch; computed length of wind fetch is 9.8 miles

At the back section of Old Greenwich, design wave heights and periods for waves generated by winds sustained from the ESE direction for a duration of 8 hours were determined for return periods of 100, 50, 25, 10, and 5 years. The ESE windspeeds, corresponding to these return periods, are 31, 29, 27, 24 and 22 miles per hour, respectively. Design wave heights and periods are shown in table 6.

c. Existing Conditions. An earthen berm of varying elevations exists, in sections, around the Shorelands. Elevation of the earthen berm ranges from 7.0 to 10.6 feet, NGVD. According to the town engineer, the berm was constructed over many years by residents of the Shorelands. Privately-owned seawalls, ranging in elevation from 11 to 15 feet, NGVD, are found in various locations along the coast.

d. Analysis of Wave Runup and Peak Overtopping Rate. The Automated Coastal Engineering System (ACES), version 1.07 "Wave Runup and Overtopping on Impermeable Structures" application, was used to estimate wave runup and peak rates of overtopping along the existing berm and seawalls. The general assumptions and limitations are that waves are normally incident to the structure, and unbroken in vicinity of the structure toe. This was assumed to apply for selected wave growth, using southwest wind data inside Greenwich Cove and east-southeast data along the coast of Long Island Sound.

TABLE 6

WIND GENERATED WAVES
OLD GREENWICH, ALONG LONG ISLAND SOUND
GREENWICH, CONNECTICUT

Period (years)	SWL (ft,NGVD)	Duration (hours)	Speed (mph)	Height (ft)	Period (sec)	Limited By
100	11.7	8	31	4.8	4.5	Fetch
50	11.2	8	29	4.4	4.3	Fetch
25	10.4	8	27	4.0	4.2	Fetch
10	9.5	8	24	3.5	3.9	Fetch
5	8.7	8	22	3.1	3.7	Fetch

Assumptions:

Winds from east southeast
Deep water wave generation
Restricted fetch; computed length of wind fetch is 17.5 miles

For each particular wave return period, a local windspeed from the southwest or east-southeast direction was assumed to be occurring during the period of wave runup and overtopping. Other parameters required for the ACES analysis were obtained from 2-foot contour maps provided by the town, survey of the earthen berm provided by the town, and tide-frequency analysis. The toe of the structure was considered the point where the structure slope intersected the nearshore slope. Depth of the structure was defined as the difference between the stillwater level associated with the particular return period and elevation of the intersection of the structure and near shore slope. Based on USGS topographic quadrangle map information, a nearshore slope of approximately 1 vertical to 15 horizontal was used. Overtopping coefficients were estimated using the Shore Protection Manual, 1984.

From 2 foot contour interval maps provided by the town, seven transects were estimated perpendicular to the shoreline of Greenwich Cove and Long Island Sound. Plate 7 shows locations of the transects.

Results for runup and overtopping rate are shown in tables 7 and 8. Runup and overtopping calculations are not valid when crest of the structure is inundated by the stillwater tide level. Runup and Overtopping calculations were not performed at any station for the 100 or 50-year storm due to the stillwater level inundating all structures during these events.

TABLE 7

WAVE RUNUP DATA
OLD GREENWICH, GREENWICH, CONNECTICUT

Transect Number on Berm or Seawall	1	2	3	4	5	6	7
Top of Structure (ft, NGVD)	8.4	9.8	9.7	10.3	11.0	11.0	11.0
Stillwater Tide Level (ft, NGVD)	Top of Runup (ft, NGVD) (Runup + Stillwater Tide Level)						
11.7	*	*	*	*	*	*	*
11.2	*	*	*	*	*	*	*
10.4	*	*	*	*	12.9	15.7	15.7
9.5	*	13.8	13.9	13.8	11.7	14.2	14.2
8.7	*	12.8	12.8	12.8	1.8	4.2	4.2

* Crest of structure below stillwater tide level; therefore, runup calculations not performed.

e. Wave Crest Transmission. Since the entire backshore of the study area is of interest, the wave height and crest elevation, associated with the 100-year storm surge as the waves propagate through the area, were computed according to the Federal Emergency Management Agency's Wave Height Analyses for Flood Insurance Studies (WHAFIS). The model takes into account transformation of the wave height due to local winds, bottom interaction effects, and presence of features such as buildings, as the wave propagates along a transect. An open space ratio of 0.45 to 0.64 was computed from the building density in the study area. In the WHAFIS computations, depth limited waves in shallow water reach a maximum breaking height equal to 0.78 times the stillwater depth, and the wave crest is 70 percent of the total wave height above the stillwater level.

The 100-year wave crest transmission was not analyzed for transect 1. This reach has a sheltered orientation in respect to design waves generated from SW winds, and there is only a short open water fetch to the west. Results of the wave crest transmission analysis for the backshore of Old Greenwich are presented in table 9 and in plates 8 through 12.

TABLE 8

PEAK WAVE OVERTOPPING RATE PER UNIT LENGTH
OLD GREENWICH, GREENWICH, CONNECTICUT

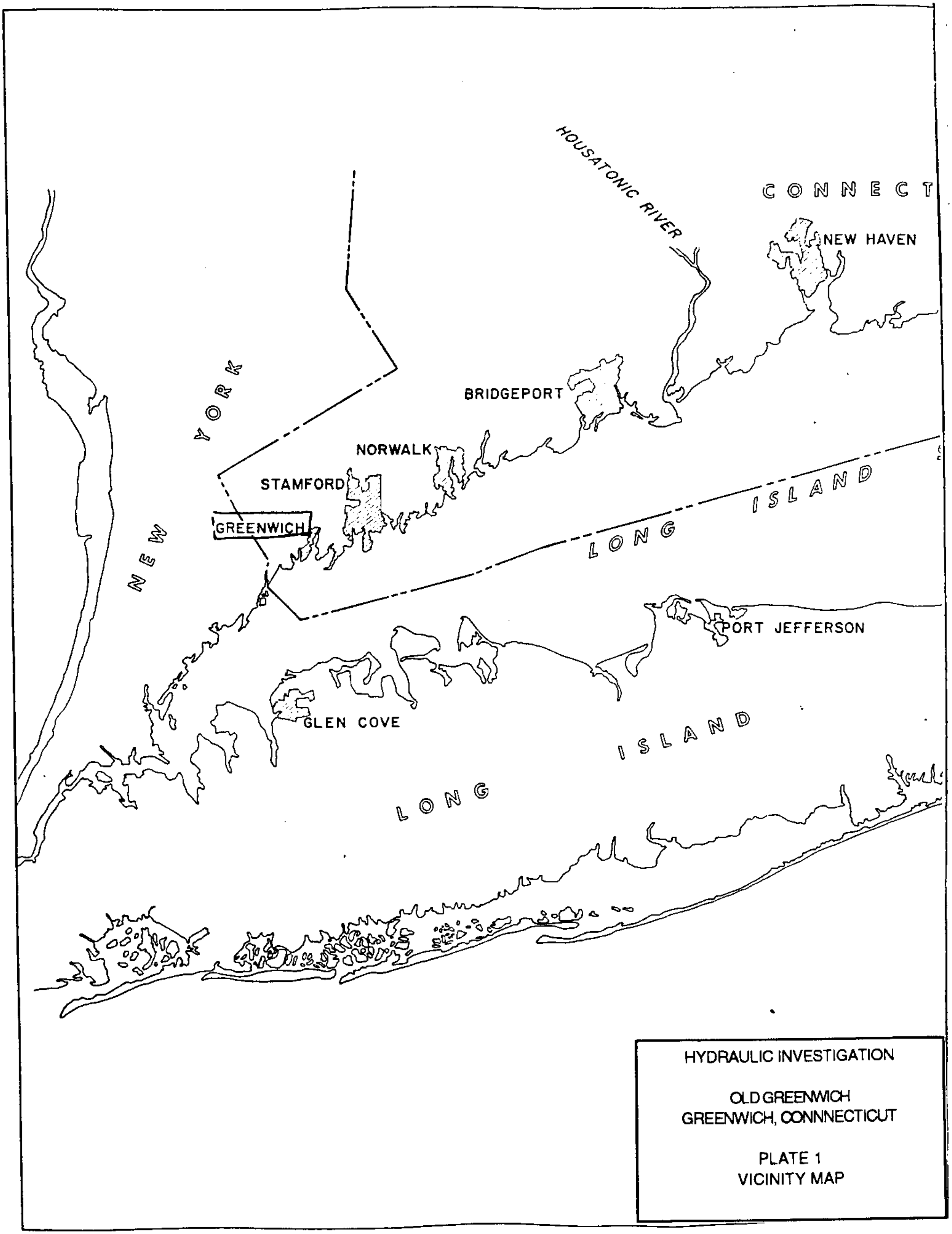
Transect Number on Berm or Seawall	1	2	3	4	5	6	7
Top of Structure (ft, NGVD)	8.4	9.8	9.7	10.3	11.0	11.0	11.0
Stillwater Tide Level (ft, NGVD)	Overtopping Rate Unit Length (CFS/LF)						
11.7	*	*	*	*	*	*	*
11.2	*	*	*	*	*	*	*
10.4	*	*	*	*	0.8	2.9	2.9
9.5	*	1.7	1.8	1.2	0.1	1.1	1.1
8.7	*	0.8	0.9	0.5	0.0	0.3	0.3

* Crest of structure below stillwater tide level; therefore, overtopping calculations not performed.

TABLE 9

100-YEAR WAVE CREST
OLD GREENWICH
TRANSMISSION ANALYSIS

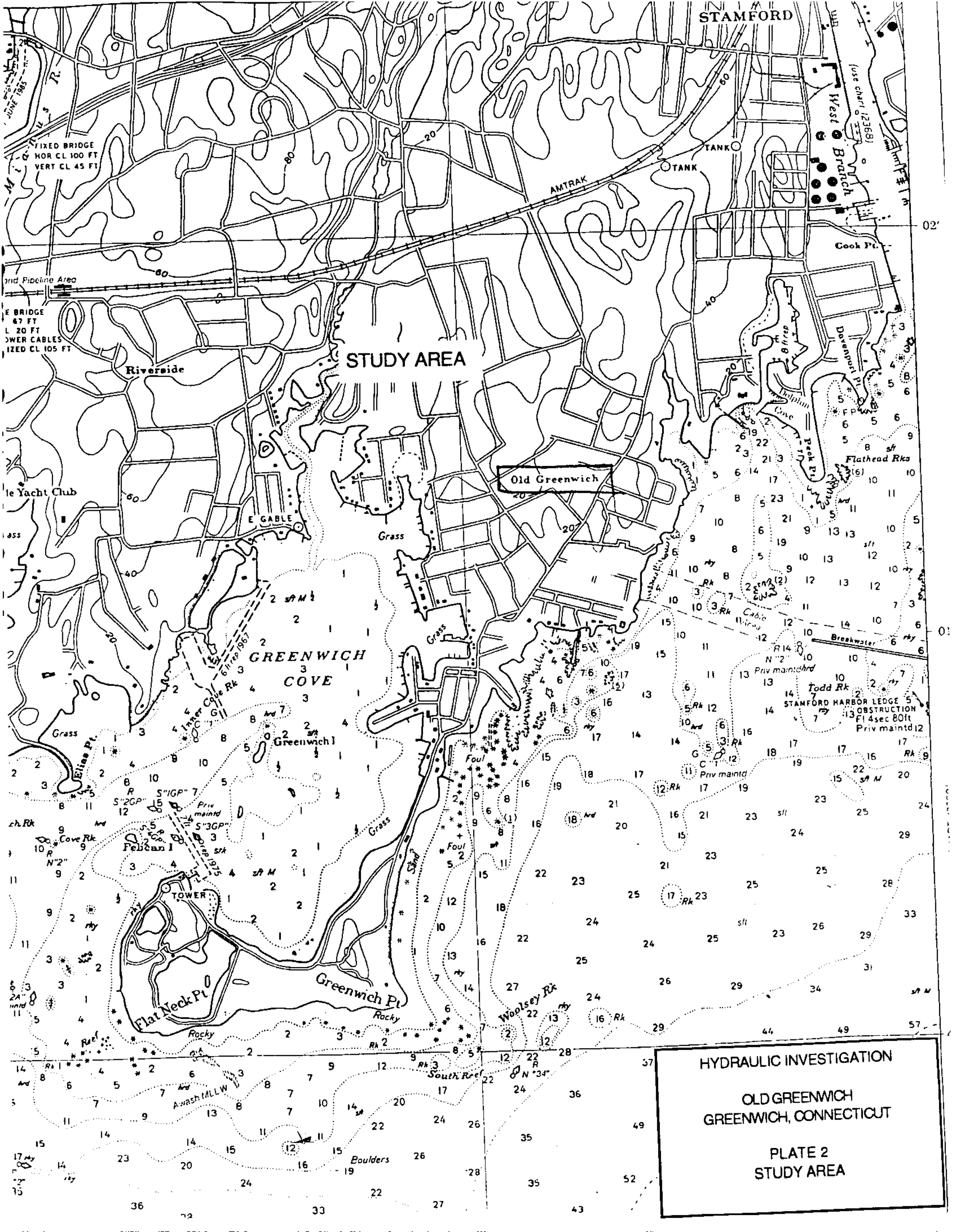
Transect No.	Location	Maximum 100-Year Wave Crest Elevation (ft, NGVD)
2	Eggleston Rd - Seaward of Berm	13.31
2	Eggleston Rd - Shoreward of Berm	12.57
2	Eggleston Rd - Centerline Marsh Meadow Lane	12.15
3	Grimes Rd - Seaward of Berm	13.31
3	Grimes Rd - Shoreward of Berm	12.62
3	Grimes Rd - Centerline Marsh Meadow Lane	12.30
5	West Way - Seaward of Wall	13.30
5	Intersection of West Way and North Way	12.40
5	Intersection of Crossway and Cove	12.60
6	Meadowbank Rd - Shoreline	15.06
6	Meadowbank Rd - 30 ft inland of seawall of seawall	13.61
6	Meadowbank Rd - 800 ft inland of seawall	13.20
7	Ledge Rd - Shoreline	15.06
7	Ledge Rd - at seawall	13.65
7	Ledge Rd - 100 feet inland of seawall	12.40
7	Ledge Rd - 300 feet inland of seawall	12.60
7	Ledge Rd - 400 feet inland of seawall	11.70



HYDRAULIC INVESTIGATION

OLD GREENWICH
GREENWICH, CONNNECTICUT

PLATE 1
VICINITY MAP



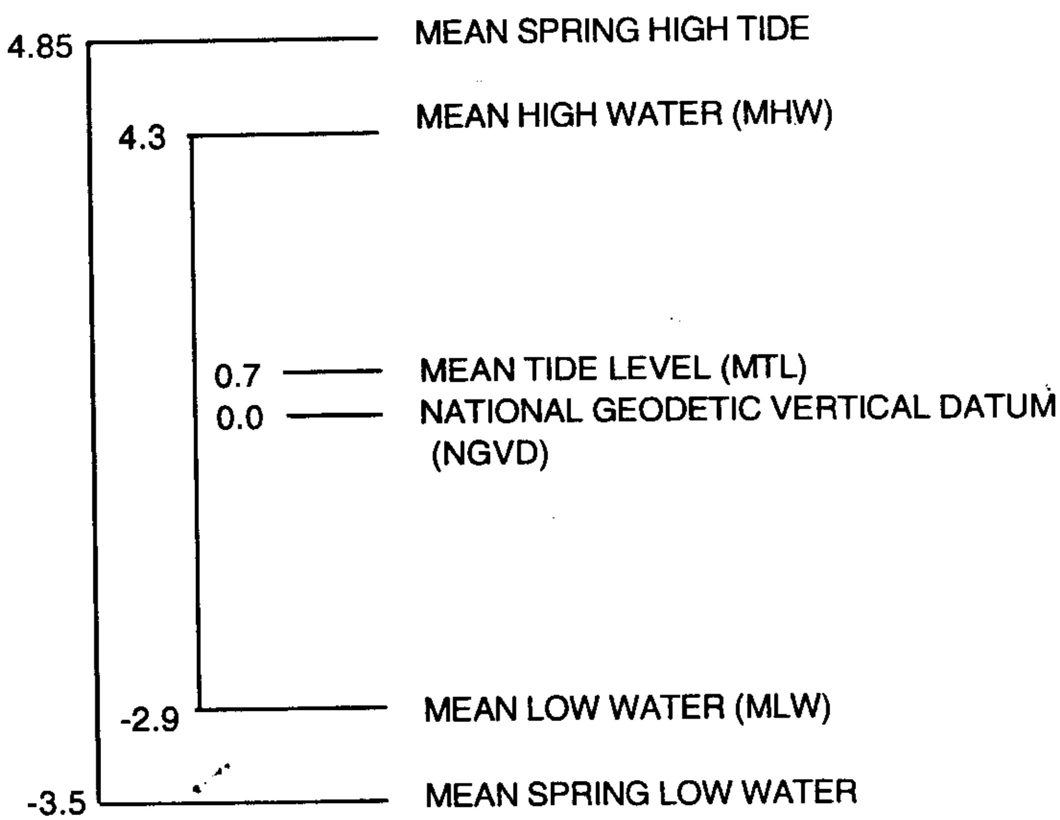
HYDRAULIC INVESTIGATION

OLD GREENWICH
GREENWICH, CONNECTICUT

PLATE 2
STUDY AREA

TIDAL DATUM PLANES
GREENWICH, CONNECTICUT

(BASED UPON CORRELATION WITH PRIMARY NOS GAGE AT BRIDGEPORT,CT)
(BASED UPON 1960 - 1978 NOS TIDAL EPOCH)



NEW ENGLAND DIVISION
U.S. ARMY, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

PLATE 3

CORPS OF ENGINEERS U S ARMY

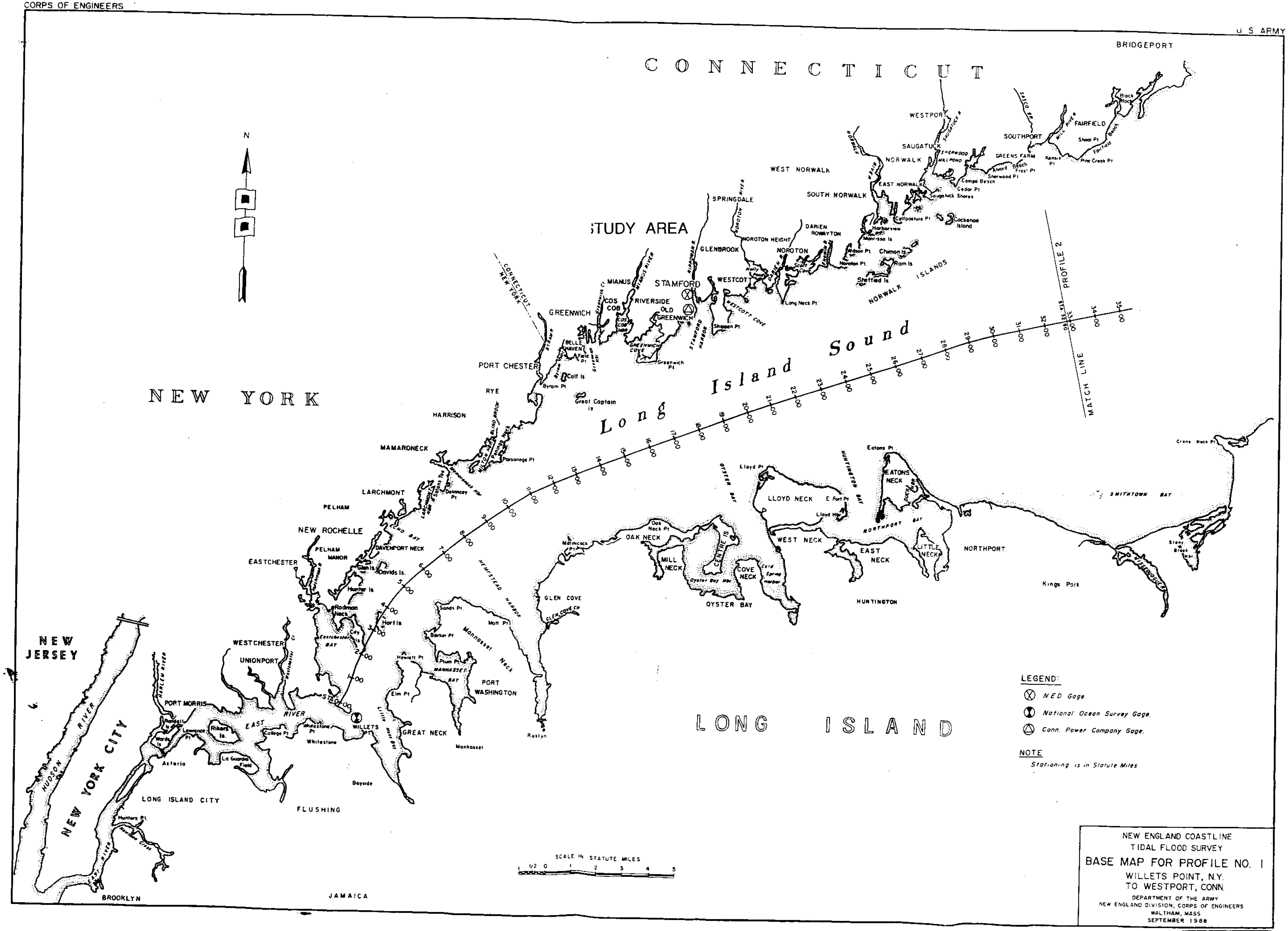
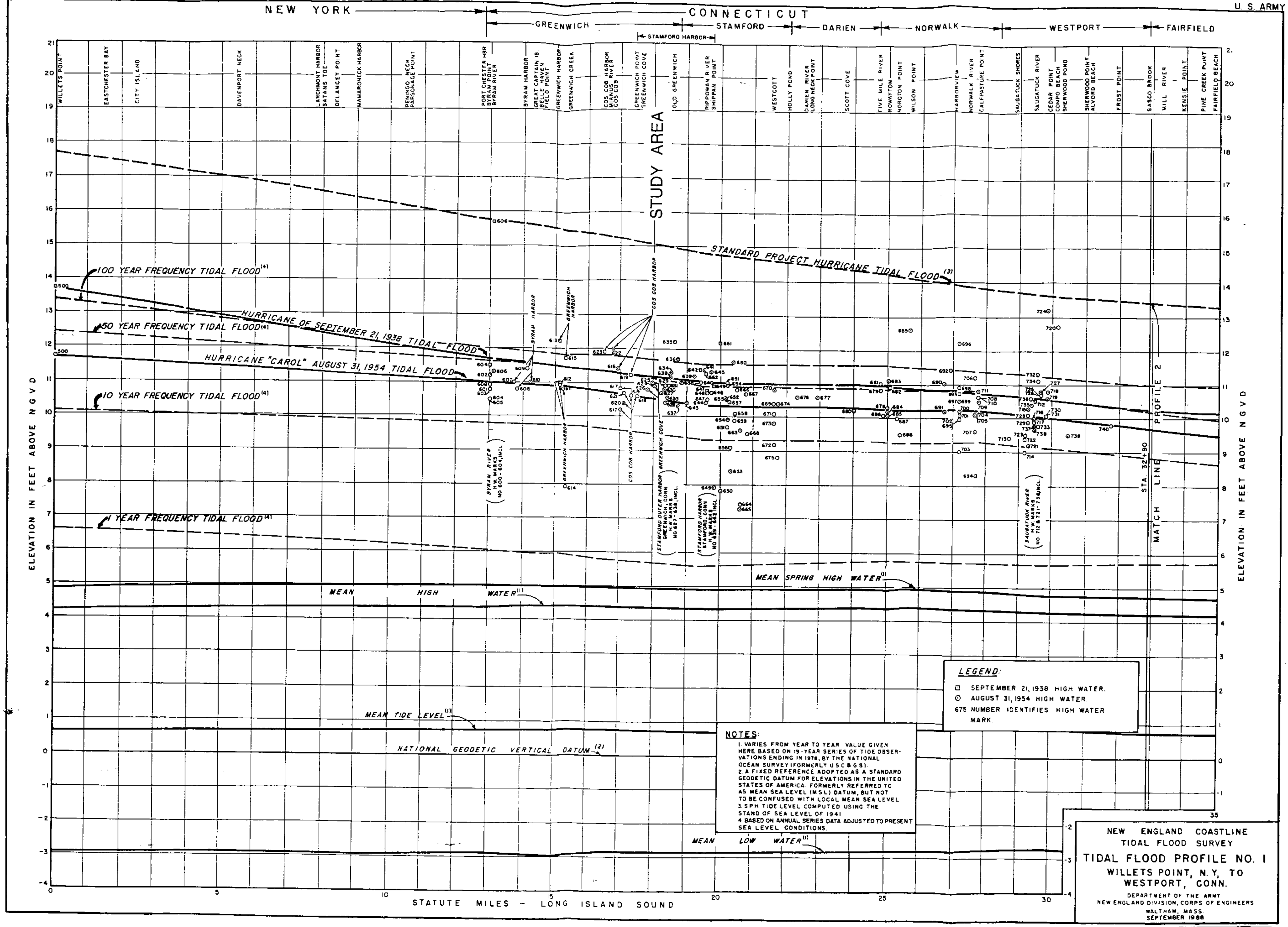


PLATE 4

CORPS OF ENGINEERS

U. S. ARMY



NOTES:

1. VARIES FROM YEAR TO YEAR VALUE GIVEN HERE BASED ON 19-YEAR SERIES OF TIDE OBSERVATIONS ENDING IN 1978, BY THE NATIONAL OCEAN SURVEY (FORMERLY U S C & G S).
2. A FIXED REFERENCE ADOPTED AS A STANDARD GEODETIC DATUM FOR ELEVATIONS IN THE UNITED STATES OF AMERICA. FORMERLY REFERRED TO AS MEAN SEA LEVEL (M S L) DATUM, BUT NOT TO BE CONFUSED WITH LOCAL MEAN SEA LEVEL
3. SPH TIDE LEVEL COMPUTED USING THE STAND OF SEA LEVEL OF 1941
4 BASED ON ANNUAL SERIES DATA ADJUSTED TO PRESENT SEA LEVEL CONDITIONS.

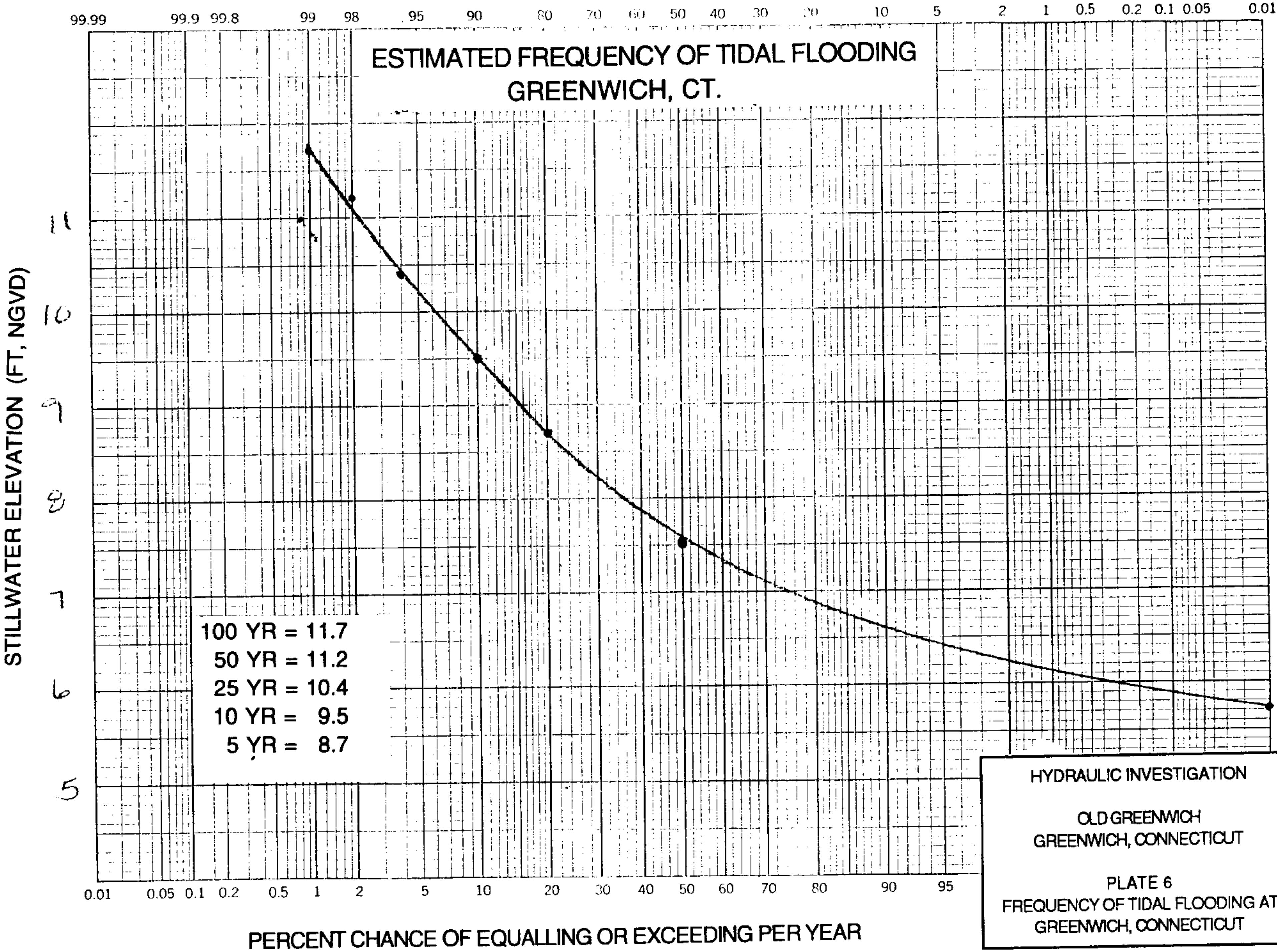
NEW ENGLAND COASTLINE
TIDAL FLOOD SURVEY

TIDAL FLOOD PROFILE NO. 1

WILLETS POINT, N. Y, TO WESTPORT, CONN.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
SEPTEMBER 1988

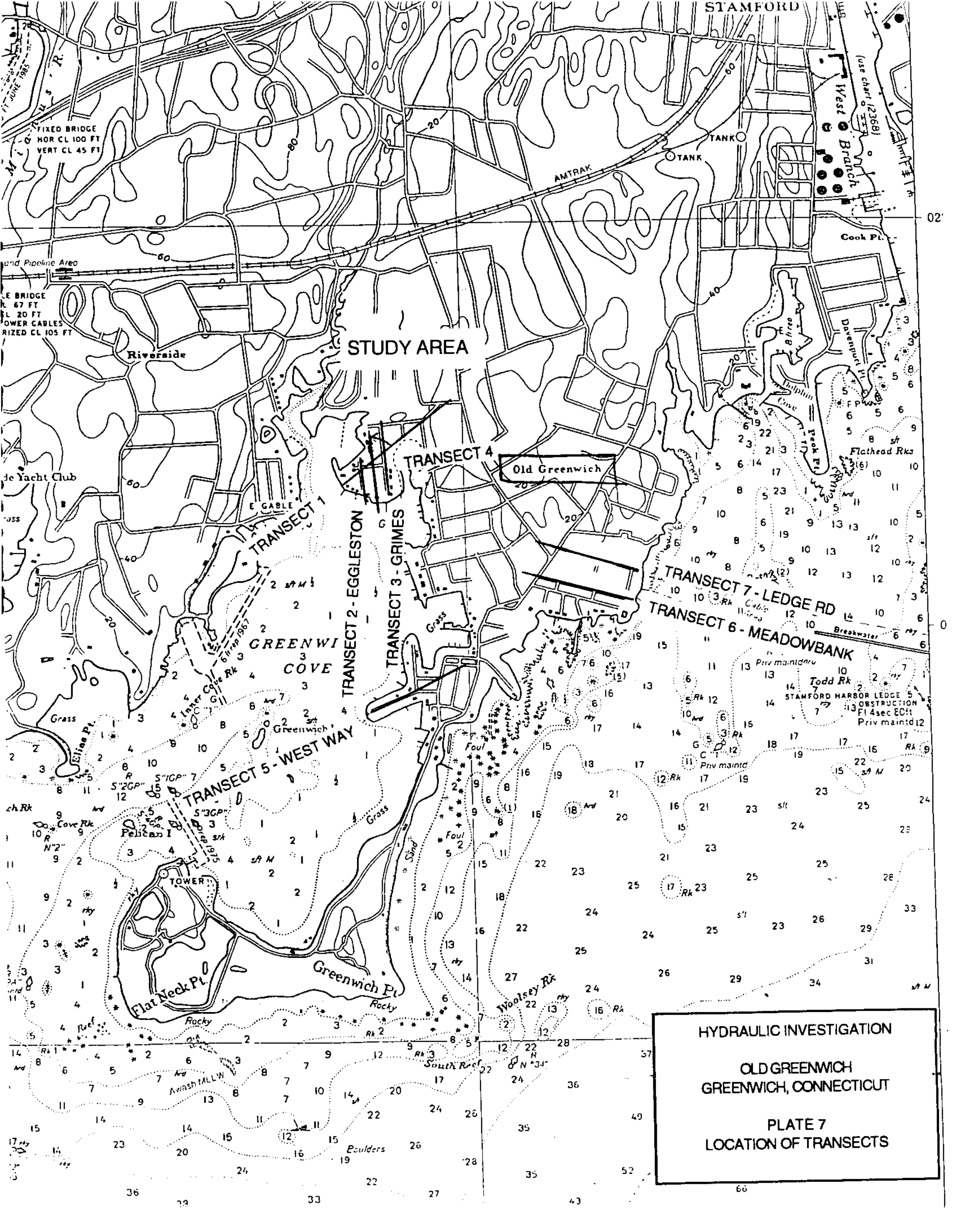
PLATE 5



HYDRAULIC INVESTIGATION

OLD GREENWICH
GREENWICH, CONNECTICUT

PLATE 6
FREQUENCY OF TIDAL FLOODING AT
GREENWICH, CONNECTICUT



HYDRAULIC INVESTIGATION

OLD GREENWICH
GREENWICH, CONNECTICUT

PLATE 7
LOCATION OF TRANSECTS

TRANSECT 2 – EGGLESTON

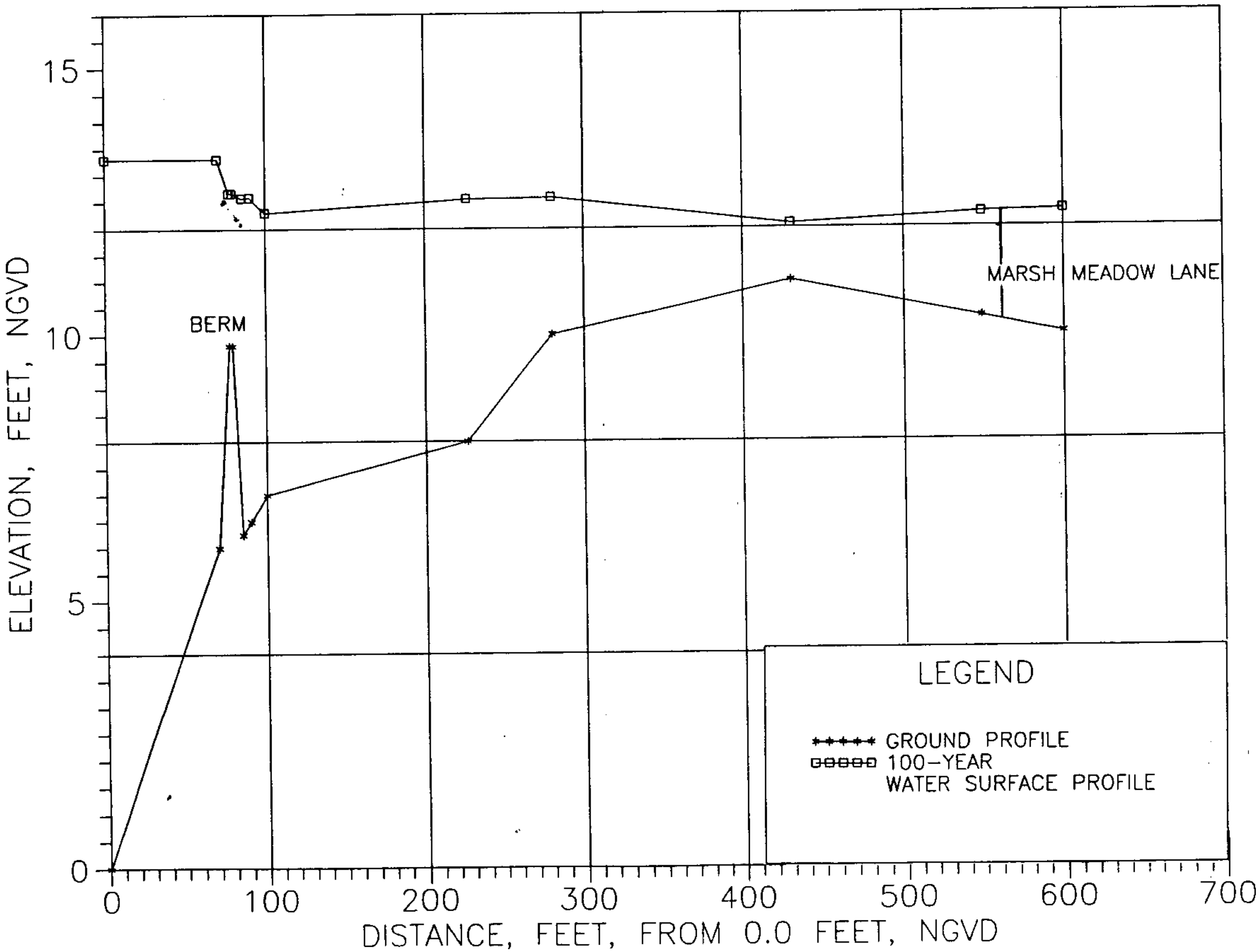


PLATE 8

TRANSECT 3 - GRIMES

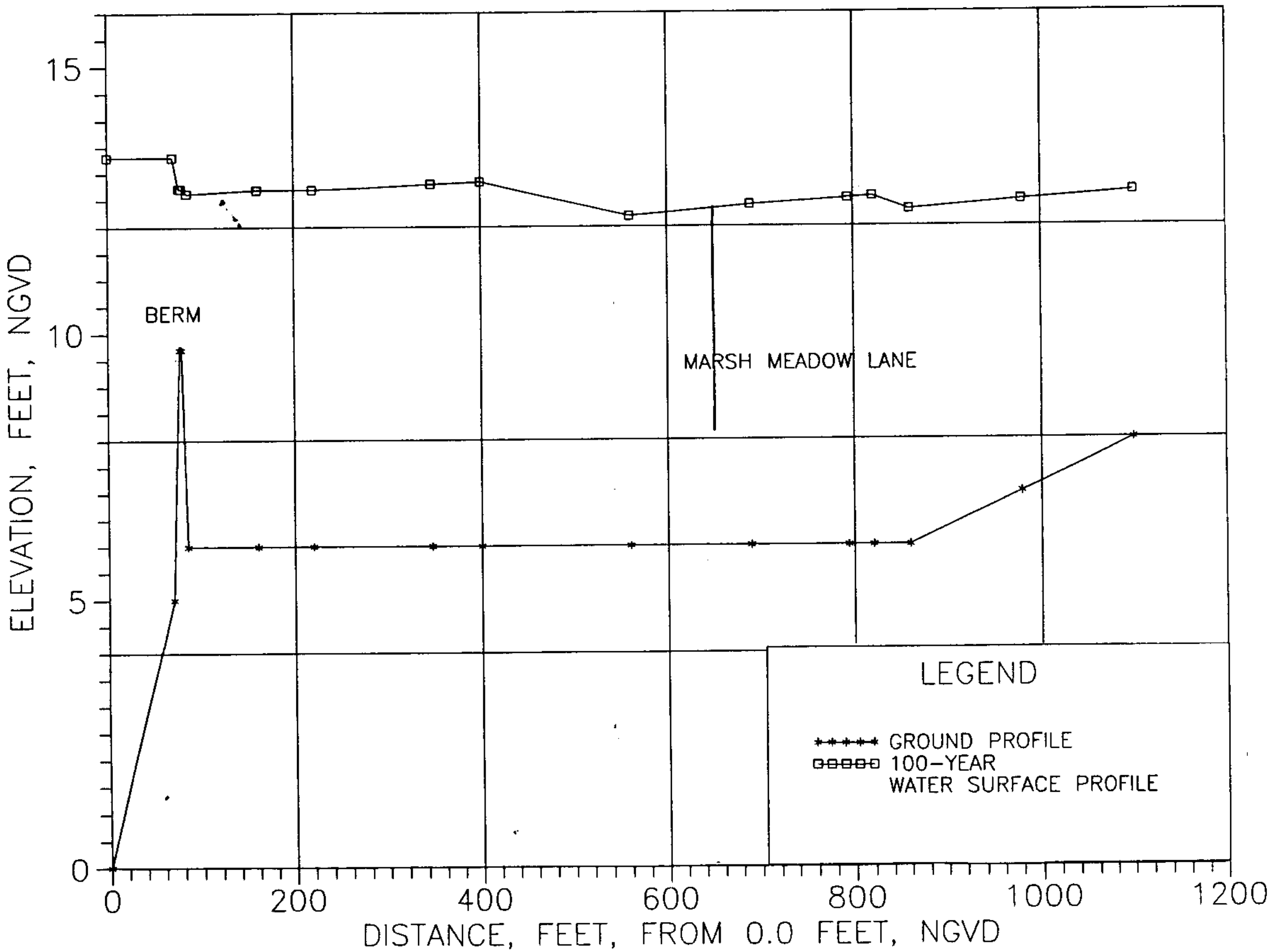
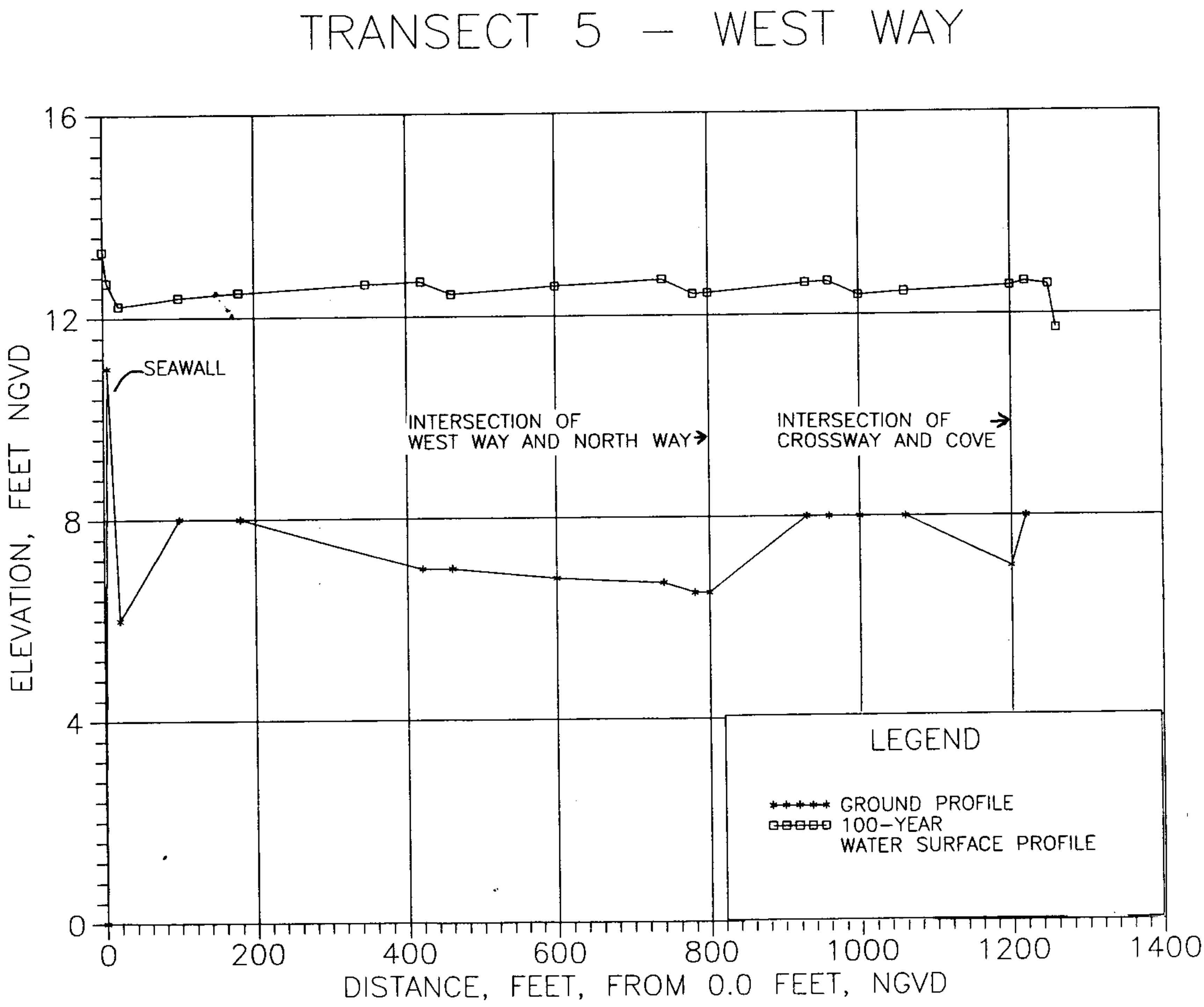


PLATE 9



TRANSECT 5 — WEST WAY
ELEVATION, FEET NGVD
DISTANCE, FEET, FROM 0.0 FEET, NGVD
0
4
8
12
16
0
200
400
600
800
1000
1200
1400
SEAWALL
INTERSECTION OF WEST WAY AND NORTH WAY
INTERSECTION OF CROSSWAY AND COVE
LEGEND
GROUND PROFILE
100-YEAR WATER SURFACE PROFILE

PLATE 10

TRANSECT 6 — MEADOWBANK ROAD

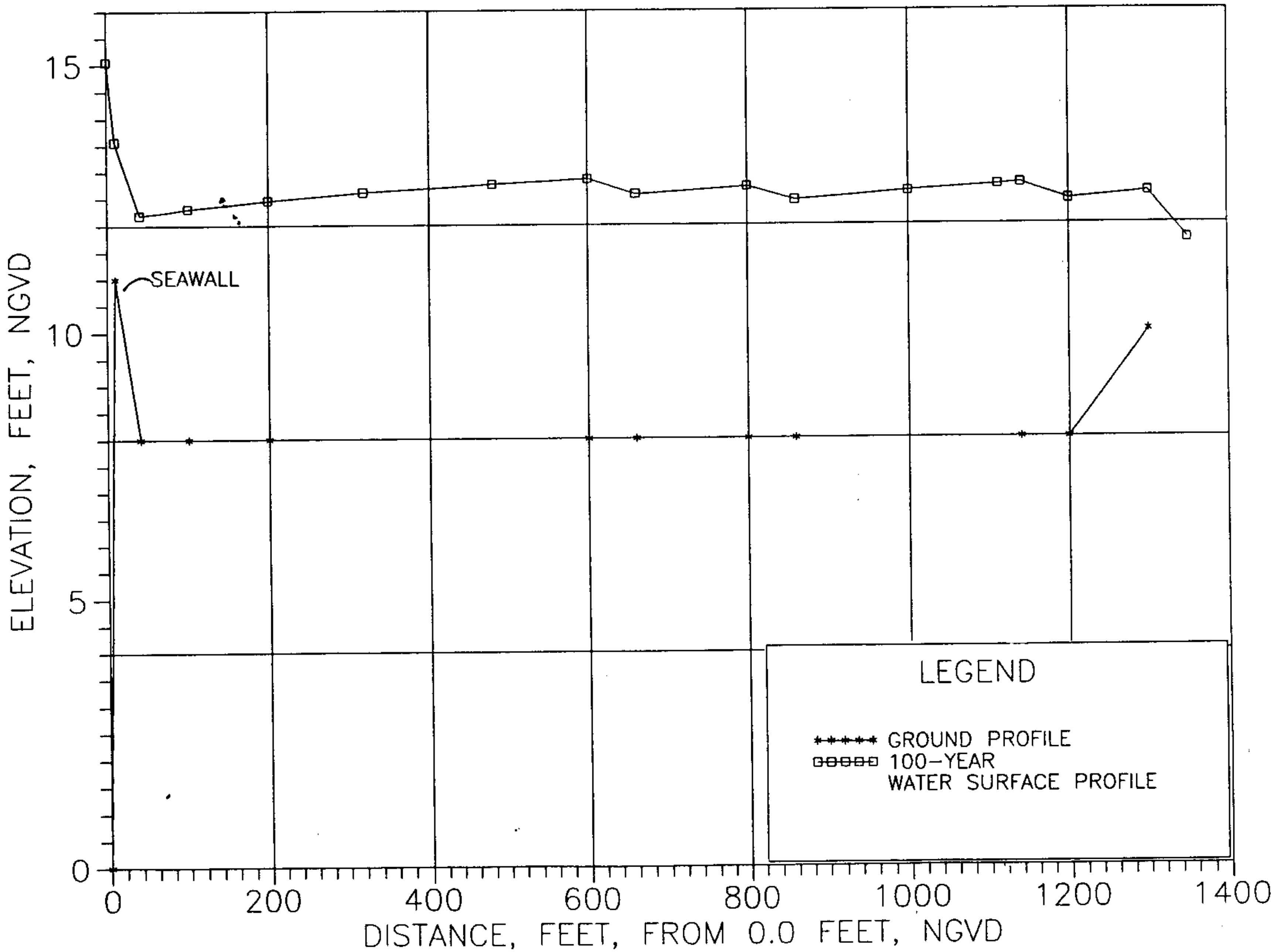
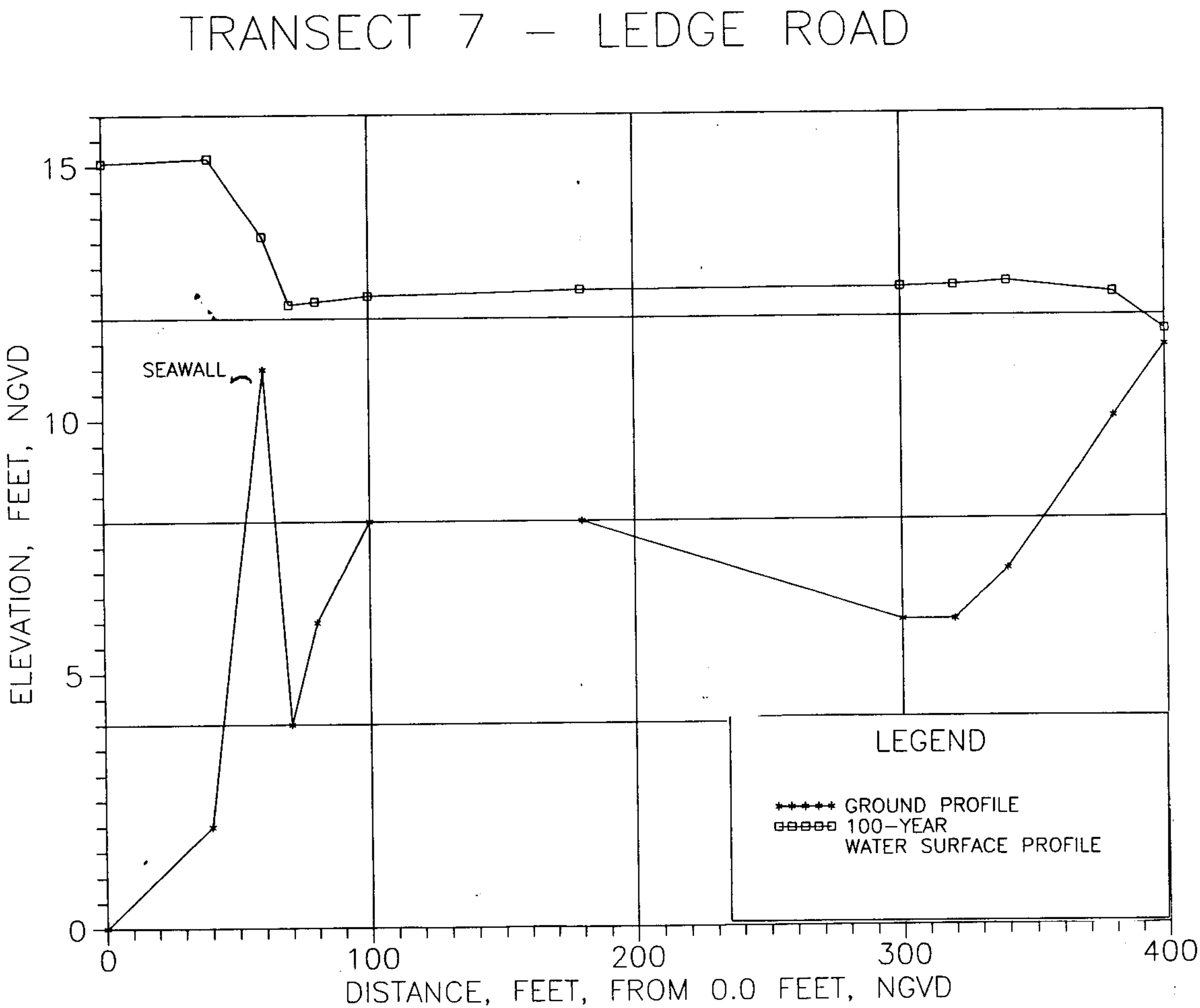


PLATE 11



TRANSECT 7 – LEDGE ROAD
ELEVATION, FEET, NGVD
15
10
5
0
SEAWALL
0
100
200
300
400
DISTANCE, FEET, FROM 0.0 FEET, NGVD
LEGEND
GROUND PROFILE
100-YEAR
WATER SURFACE PROFILE

PLATE 12

APPENDIX B

HURRICANE AND STORM DAMAGE REDUCTION STUDY
SECTION 103 OF THE RIVER AND HARBOR ACT OF 1962

OLD GREENWICH
GREENWICH, CONNECTICUT

APPENDIX B

ECONOMIC ANALYSIS

Prepared by:

Economic & Resource Analysis Branch
Impact Analysis Division
Planning Directorate

New England Division
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424 Trapelo Road
Waltham, Massachusetts 02254-9149

Old Greenwich, Greenwich, Connecticut
Section 103 Reconnaissance Study
Economic Analysis

Introduction

The purpose of this analysis is to identify and evaluate the economic feasibility of providing flood damage protection to portions of Old Greenwich in Greenwich, Connecticut. The town of Greenwich is located in south-western Connecticut, on the border of New York State, and on the shore of Long Island Sound. Old Greenwich is located east of Greenwich Cove. The study area includes a residential portion of Greenwich known as Shorelands, as well as houses in the 100 year floodplain around the shoreline of the Old Greenwich area. The area has suffered coastal flooding in the past, flooding which was particularly severe in the storm of December 12, 1992.

This economic analysis includes a description of the study area, estimates of the recurring and expected annual flood damages for the study area, calculation of the annual benefits derived from preventing those damages, and a determination of the economic justification of the proposed improvement plan by calculating the benefit to cost ratio of the plan.

Methodology

A proposed project is considered economically justified if it has a benefit to cost ratio equal to or greater than 1.0, that is, if the benefits of the project equal or outweigh the costs of the project. In a general sense, the economic benefits of a project are determined by comparing the without project condition to the with project condition, and evaluating the difference between the two conditions.

In accordance with Corps of Engineers guidelines, the benefit to cost ratio for the improvement plan examined is calculated by comparing the benefits and costs of the plan in average annual equivalent terms. Costs and benefits are converted to average annual equivalents as needed, based on the fiscal year 1994 federal interest rate for water resources projects of 8 percent, and based on a 50 year period of analysis. All costs and benefits contained in this analysis are stated at the 1994 price level, and the analysis is performed at the reconnaissance level of detail.

Description of the Study Area

The study area contains 124 houses which are located in the 100 year flood plain and which also have first floor elevations below the 100 year flood elevation. Those 124 houses were analyzed in detail in this analysis. The houses are primarily large, one to three story single family homes, in very good condition. The study area includes houses located on Grimes Road, Mortimer Street, Meadow Place, Keoferram Road, Little Cove Road, Shore Road, East Point Lane, Shoreham Club Road, West Way, North Way, West Crossway, North Crossway, Cove Road, Rocky Point Road, Meadowbank Road, and Ledge Road. In all, the 124 houses in the study area have a total assessed value, including land and structures, of nearly $42 million. The study area contains no commercial or other non-residential development.

Economic Setting

Located just over the New York border, the town of Greenwich can be considered part of the greater metropolitan area of New York City. In general, the town is suburban in nature, with clusters of retail development, and with some areas more densely populated than others. According to the 1990 US Census, in 1990 Greenwich had a total population of 58,441 and a median family income of $80,558, one of the highest median family incomes in the country.

Existing Conditions

The study area is subjected to flood damages from coastal storms, and suffered extensive flood damages in the recent coastal storm of December 12, 1992. After the December 1992 storm, claims in the study area to the Federal Emergency Management Agency under the National Flood Insurance Program totalled $1.5 million. Damages suffered included structural damages and damages to contents. Many houses, particularly in the shorelands area, suffered first floor flooding, with the associated very high damages. In response to the severe flood damages that have been experienced in the past, several of the property owners in the Shorelands area are raising their houses to elevate their first floor above the flood level, thus preventing significant damages in the future.

Without Project Condition

It is projected for the without project condition that no measures providing permanent, effective protection to the study area from flood damages will be constructed in the study area by the town, state, or federal interests. As a result, in the without project condition, it was assumed that flood damages similar to those that have been experienced in the past will continue to be experienced in the study area in the future.

With Project Condition

The with project condition examined in detail for this analysis consists of elevating the structures in the study area to an elevation above the 100 year flood elevation. Raising the structures would prevent major damages from flooding, leaving only minor grounds and basement damages to be suffered in most flood events. The houses would be raised in accordance with the regulations of the Federal Emergency Management Agency (FEMA).

Structure Inventory

In order to identify which specific structures would be included in this study, a survey of the 100 year flood plain in the study area was conducted. In the survey, structures within the 100 year floodplain and with first floor elevations below the 100 year flood elevation, which is elevation 12 feet NGVD in some portions of the study area and elevation 13 feet NGVD in other portions of the study area, were identified. First floor elevation estimates were made based on available topographic mapping. Once the structures to be studied were identified, and the first floor elevations of the structures were determined, the structures were then categorized by size and type of structure.

Based on the structure inventory completed for this study, the structures included in the analysis have first floor elevations as distributed in Table 1, below.

Table 1

Structure Inventory

Area	Elevation 7	8	9	10	11	12	13	Total
Shorelands	0	0	7	2	8	7	0	24
Remaining Areas	2	3	10	13	33	30	9	100
Total	2	3	17	15	41	37	9	124

Recurring Losses

Once the structures were categorized by size and type, typical stage-damage functions for each category were used to estimate the flood damage that would be likely to occur at various flood elevations. The typical stage-damage functions used had been developed for previous Corps studies, adjusted and updated to reflect depreciated repair and replacement costs for the structures in the Greenwich study area. The damages in the typical stage-damage functions used are estimated in one foot increments, from the basement to six feet above the first floor. The damage functions include damage estimates for structural damage, damage to contents, damage to utilities, damage to outside grounds, and estimated non-physical losses such as costs for temporary relocation during a flood.

The stage-damage functions assigned to each of the different structures were then aggregated, based on first floor elevations, to determine the total stage-damage function for the entire study area. The total stage-damage curve for the study area was then combined with the stage-frequency curve that was developed for the study area, in order to determine the damage-frequency relationships. The damages that are expected to occur at each flood event are termed the recurring losses for the study area. The recurring losses for a range of events are shown in Table 2, below.

Table 2
Recurring Losses

Probability (%)	Frequency (year)	Stage (feet)	Estimated Damages ($)
100	1	5.7	$ 0
50	2	7.5	$ 106,900
30	3.3	8.2	$ 287,600
20	5	8.7	$ 680,900
10	10	9.5	$1,461,400
5	20	10.2	$2,426,100
4	25	10.4	$2,846,400
2	50	11.2	$4,616,400
1	100	11.8	$5,889,200

Expected Annual Damages

Expected annual damages are calculated by multiplying the predicted damages for each flood event by the annual percentage chance that each event will occur. The resulting expected damages at each event, given each event's probability of occurrence, are then added together to yield the total expected annual damages for the study area. The expected annual damage figure represents the average annual damage that could be expected to occur based on the weighted probabilities of the complete range of storm events. Based on these calculations, the total expected annual damages for the study area under existing conditions were calculated to equal $530,800.

Calculation of Benefits to Raising

In Corps of Engineers flood damage reduction studies, the effectiveness of a flood damage reduction plan is measured by the extent to which it reduces expected annual damages. In order to determine the benefits to raising the houses in the study area, the expected annual damages under existing conditions, without raising the houses, are compared to the expected annual damages with raising the houses. The difference between the two expected annual damage figures equals the benefits to raising the houses.

The expected annual damages under existing conditions are estimated at $530,000, as described in the section above. In order to estimate the expected annual damages with raising the houses, the following methodology was used. After calculating the expected annual damages under existing conditions, the stage damage function for each house was then adjusted so that the damages at the first floor level were elevated to one foot above the appropriate 100 year flood elevation. The expected annual damages were then recalculated to reflect this with-raising condition. With raising, the expected annual damages were calculated to equal $42,400, yielage-damage functions used for each house but which would not be affected by raising. For example, the typical stage-damage functions include estimates for damage to the grounds and outside items, as well as non-physical costs, neither of which would be reduced with raising the house. In order to adjust the benefits to remove these non-raisable elements, the benefits were multiplied by 90 percent, since approximately 10 percent of the damages at each stage of the typical stage-damage functions were determined to be non-raisables. Making this adjustment yielded total annual benefits with raising of $439,600.

Risk and Uncertainty

Current Corps of Engineers regulations require that areas of risk and uncertainty be explicitly addressed in the detailed, feasibility phase of analysis. Areas of uncertainty that have been identified in this reconnaissance level analysis that would be addressed in the feasibility level analysis are as follows. First, as a simplifying assumption for this analysis, it was assumed that, for houses with basements, the start of damage was at 2 feet below the first floor elevation. In the feasibility phase, as part of the survey, the start of damage elevation would be determined for each specific house. Second, in the feasibility phase, a survey of the property owners would be conducted, in order to determine more accurately the extent and type of damages suffered in recent past flooding events. Third, in the analysis of the areas outside of the Shorelands area, five houses were identified which appeared too low to fit within the hydrologic zone. In order to prevent unreasonable results, those five houses were removed from this analysis. In the feasibility phase, these houses would be examined more closely in order to resolve this problem.

Economic Justification

In order for a federal project to be considered economically justified, it must have a benefit to cost ratio equal to 1.0 or greater. The specifications and costs of the proposed house raising project are detailed in the main report and in the Engineering Appendix. The total annual benefits, total annual costs, benefit to cost ratio, and net annual benefits for the proposed project are shown in Table 3, below.

Table 3
Economic Justification

Alternative	Annual Benefits	Annual Costs	Benefit to Cost Ratio	Net Annual Benefits
Raise 124 Houses	$439,600	$419,900	1.05	$19,700

APPENDIX C

HURRICANE AND STORM DAMAGE REDUCTION STUDY
SECTION 103 OF THE RIVER AND HARBOR ACT OF 1962

OLD GREENWICH
GREENWICH, CONNECTICUT

APPENDIX C

ENVIRONMENTAL RESOURCES

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TABLE OF CONTENTS

1. INTRODUCTION

The Corps of Engineers is conducting a reconnaissance study of coastal flooding in Old Greenwich, Greenwich, Connecticut. Engineering and economic studies indicate that flooding causes considerable damage to residential structures in the community. Alternatives under consideration to reduce flood damage include constructing a system of dikes and floodwalls and raising first floor elevations above the 100 year flood level.

This report is a preliminary environmental evaluation of potential flood damage reduction measures. The report describes environmental resources in the study area, assesses the environmental affects of flood control alternatives, and discusses required Feasibility level environmental studies.

2. ALTERNATIVES

a. Proposed Alternative

The proposed alternative is to raise the first floor elevations of individual structures to above the 100 year flood elevation. Up to 124 structures would be raised.

b. Other Alternatives

No Federal Action:

Under this alternative, property owners, the Town of Greenwich, and the State of Connecticut would be responsible for providing flood control. Until action was taken at the local level, Old Greenwich would continue to be at risk to flood damage by coastal storms and hurricanes.

Construction of Dikes and Seawalls:

In the Shorelands area of Old Greenwich perimeter or ring dikes could be constructed to reduce flood damage. A long perimeter dike (ca. 4,000 linear ft.) with long tie ins to the north, approximately 500 feet of sea wall, and at least two flood gates would be needed to protect the area. Alternatively, smaller ring dikes could be constructed around groups of homes needing protection.

Additional seawall would also be needed to protect the Long Island Sound side of Old Greenwich. Most existing privately built seawalls in the area would need to be rebuilt to Corps specifications.

Early in the planning process the dike/seawall alternative was found not to be cost effective. Also, State of Connecticut regulatory agencies typically strongly oppose structural solutions to coastal flooding.

3. ENVIRONMENTAL SETTING

a. General Setting

Greenwich is located in Fairfield County, in southwestern Connecticut (see Main Report, Plate 1). The study focuses on a one square mile section of eastern Greenwich known as "Old Greenwich" (see Main Report, Plate 2). Old Greenwich is situated on a peninsula bordered to the east by Long Island Sound and to the West by Greenwich Cove. A narrow causeway connects Old Greenwich to Greenwich Point Park to the south.

The topography of Old Greenwich is generally flat, with most areas having an elevation less than 30 ft. NGVD. Portions of the area's 4 miles long shoreline are protected by privately constructed earthen dikes or floodwalls. The "Shorelands", a private residential area situated on low ground adjacent to Greenwich Cove, is ringed by a loosely connected series of earthen dikes.

Old Greenwich is a year-round residential community. Several hundred homes are present, including approximately 124 with first floor elevations below the 100 year flood elevation. During the last several decades, the area has been flooded numerous times by coastal storms and hurricanes (see Main Report). Homes along both Greenwich Cove and Long Island Sound are at risk.

b. Water Quality and Tidal Hydrology

Water quality in most of Greenwich Cove and adjacent waters is rated as Class SB/SA.

A small area within the inner cove is classified as SB. SB/SA classification indicates that the designated classification (SA) is not being attained. Non attainment in Greenwich Cove is due to occasional elevated bacterial levels.

The mean tidal range, and mean spring tidal ranges are 7.2 and 8.3 feet, respectively. Maximum and minimum predicted astronomic tide ranges are about 12.0 and 2.9 feet. Depending on location, the 100 year flood elevation in Old Greenwich ranges between 12 and 13 feet (see Main Report). The western (Greenwich Cove) shoreline is somewhat protected by Greenwich Point, while the east side is fully exposed to Long Island Sound and subject to more severe wave action.

c. Aquatic Resources

Part of Old Greenwich is built upon filled areas which were once saltmarsh or mudflat. Extensive intertidal mudflats are still present in Greenwich Cove (see Plate C-1). Tidal flats are also present to a lesser extent along the more exposed eastern shoreline. Saltmarsh dominated by smooth cordgrass is present along much of the Greenwich Cove shoreline. Stands vary from a few feet wide to more than 100 feet wide. Marsh development in the Shorelands area is most extensive east and south-south west of Grimes Road, and west of Shorelands Road. Other species present include salt meadow grass, spike grass, and common glasswort. Baybery, goldenrod, switchgrass, and other grasses commonly occur at higher tidal elevations. Stands of reed occur along the margins of the marsh located east of Grimes Road.

Mudflats in Greenwich Cove provide excellent shellfish habitat (Zeranski, 1994). Quahogs and oysters are most abundant, followed by softshell clams, razor clams, and mussels. Legislation enacted years ago banned commercial shellfishing in Greenwich Cove. Recreational shellfishing is permitted (except during the summer) along the causeway between Old Greenwich and Greenwich Point and between Greenwich Point and Sand (Pelican) Island. Commercial oyster beds are present offshore to the south and east of Greenwich Point. Some lobster fishing occurs east of Greenwich Point.

Although no commercial fishing occurs in Greenwich Cove, recreational fishing for bluefish and stripped bass occurs along Greenwich Point. The nearby Mianus River supports runs of alewife, eel, smelt, sea run brown trout, and shad. Atlantic silversides and other forage fish are likely to inhabit near shore tidal flats and saltmarsh.

Harbor seals frequently occur near Greenwich Point in winter. Northern diamondback terrapin nest on Sand Island and possibly the Causeway.

d. Terrestrial Resources

Most of Old Greenwich is developed as a residential community. Vegetation consists mainly of lawns, landscaped with native or exotic trees and shrubs. Wildlife likely to occur in the area include raccoon, gray squirrel, rabbit, and skunk. Birds likely to nest in the area include American robin, starling, rock dove, house sparrow, house finch, red wing blackbird, and bluejay. Many other birds occur in the area as migrants or transients. An osprey nest (the only one in the area) is present at nearby Cos Cob Harbor.

Despite their proximity to highly developed areas, Greenwich Cove tidal flats provide excellent shorebird and waterfowl habitat. Shorebirds such as ruddy turnstone, black-bellied plover, and sanderling are common during the winter. Flocks of bufflehead and scaup duck are also common during the winter. Least tern, common tern, and gulls nest offshore and commonly feed in the cove during the summer (nesting occurs off-shore).

e. Rare, Threatened, and Endangered Species

State listed species known to occur in the project area include two special concern species (Osprey and common tern) and the threatened least tern (see above).

Aside from transient peregrine falcons and sea turtles, no federally listed threatened or endangered species are likely to occur in the project area.

f. Historic and Archaeological Resources

At the time of the European settlement of Connecticut, four Native American groups occupied the southern portion of what is today Greenwich: the Miossehassaky, Petuquapaen, Asamuck, and Patomuck tribes. This area was one of the most thickly settled areas of the region; however, the combined Dutch and English forces annihilated the main village in 1644.

This area was first explored by the Dutch from New Amsterdam (New York) who claimed it prior to 1620. No actual settlement was made until 1633 when Dutch Point, Hartford was settled followed by Windsor, Wethersfield, and Saybrook. The English also settled Windsor, Wethersfield, and Hartford.

The first settlement of Greenwich occurred in July 1640 when Captain Daniel Patrick and Robert Feakes, formerly of Watertown, Massachusetts, as agents for the New Haven Colony, landed at Greenwich Point (Old Greenwich) which the Indians called Monakewego and purchased lands from them between the Asamuck and Patomuck Rivers. Greenwich, by an agreement between the Dutch governor of New Amsterdam and the English in Hartford in 1650, was surrendered to the New Haven Colony. It was still a part of the town of Stamford until 1665 when it officially became a town (Mead 1979).

Greenwich developed primarily as a farming community and produced for home consumption and export corn, grain, potatoes, apples, hay, and livestock. The advent of the railroad in 1848 meant that Greenwich residents has a faster way of shipping farm products to New York. Other trades continued as before by water including packet boats which plied Long Island Sound. Fishing was a profitable enterprise with a number of residents listed as "oystermen".

During this period (1820-65) Greenwich remained a country town with agriculture as the main subsistence. All land was crop land during this period. The only commercial establishments were a few stores and offices on the Post Road, on the docks, and on the railroad station.

The rise of the railroad also contributed to the decline of the farming economy in Greenwich by bringing produce from the West. However, it also brought New Yorkers who purchased the former farmland and erected huge waterfront mansions. This led to the prospering of the town as a summer resort industry as many residents rented out their waterfront properties during the summer. By the turn of the century, many of these residences became year round homes. The character of Greenwich at this time was as a bustling, prosperous community.

By the beginning of the 20th Century, Greenwich reached a new era of prosperity. The wealthy purchased large tracts of land and kept the town from turning into a manufacturing center. Instead, the transition was made from an agricultural community to a prosperous residential suburb. The completion of the Connecticut Turnpike in 1957, a superhighway which vastly improved travel from Boston to New York made Greenwich a prime business location. Preservation also became important as residents became concerned about the woods, gardens, rivers, and beaches which surrounded them and which for so long they had taken for granted (Greenwich Historical Society 1990).

A check of the archaeological site files at the University of Connecticut indicated no known prehistoric or historic archaeological resources in the proposed project area. One prehistoric site was located north of the Shorelands area and consisted of the remains of an Archaic/Woodland period campsite which was described as mostly destroyed. Two additional prehistoric sites are noted for the Greenwich Point Park area which is south of proposed study locations.

g. Socio-Economic Resources

Southwestern Connecticut, including Greenwich, is heavily urbanized. Greenwich has a population of 58,441, or approximately 1155 persons per square mile (1990 U.S. Census data). The town has a median household income of $65,072 (1989 dollars), well above the $41,721 median income for Connecticut. Most workers are managers or professionals, and many commute to the New York City metropolitan area.

Old Greenwich is primarily a residential community. Commercial development is limited, and there is no significant industry. Home values in Greenwich typically range between 600,000 and 800,000 dollars. Average sale price of homes in Old Greenwich between July 1993 and July 1994 was about $600,000.

Old Greenwich is connected via a causeway to Greenwich Point Park, a heavily used recreational area. Facilities present at he park include a beach, change houses, rest rooms, a museum, nature trails, a club house, and concessions. Visitation is approximately 1,000,000 persons per year, and up to 25,000 per day. During the summer months, access to the park is limited to only Greenwich residents. A public pier is also present off Grimes Road in the Shorelands area.

4. ENVIRONMENTAL AFFECTS

a. Water Quality

The proposed alternative (raising first floor elevations) would have no impact on water quality. Standard erosion and sedimentation control measures would be installed as needed during construction to protect adjacent waters and wetlands.

Construction of dikes or floodwalls would require work in the water and result in temporary, localized increase in turbidity.

b. Aquatic Resources

The proposed alternative would have no impact on aquatic resources.

Construction of perimeter dikes and floodwalls would result in loss of substantial saltmarsh and mudflat habitat. Connecticut has placed a high priority on protecting the state's remaining intertidal habitat, and such loses would not be acceptable to permitting agencies.

c. Terrestrial Resources

When raising homes, some trees and shrubs would probably need to be cleared to gain construction access. Lost vegetation would be replanted.

Construction of perimeter dikes and floodwalls would result in loss of some trees and shrubs. Although Corps regulations preclude planting trees and shrubs on or near dikes and floodwalls, in many cases it would be possible to replant vegetation elsewhere on the same lot.

d. Rare, Threatened, and Endangered Species

Neither alternative would adversely impact any state or federally listed species.

e. Historic and Archaeological Resources

The raising of structures is not likely to effect cultural resources. The homes to be raised are located in areas which have previously been disturbed by construction activities. However, further research may be required in order to assess the potential significance of many of the homes and/or neighborhoods within the study area which may qualify for listing on the National Register of Historic Places. In these cases, the raising of homes would need to be coordinated with the Connecticut State Historic Preservation Officer.

However, this is a preliminary investigation. If this project proceeds to a further stage in the planning process, then a detailed shore protection plan will be selected. At that time, this plan will be evaluated for its effects upon cultural resources and formal comments will be requested to satisfy Section 106 of the National Historic Preservation Act of 1966, as amended. The Connecticut State Historic Preservation Officer is expected to concur with these determinations.

f. Socio-Economic Resources

Both alternatives would greatly reduce flood damage in Old Greenwich. The proposed alternative (raising first floor elevations) would probably leave some homes susceptible to flood damage because their owners would choose not to participate in the project. The dike/floodwall alternative would be designed to protect all of the homes at risk.

Raising first floor elevations would have an adverse aesthetic impact on many structures. Severity of the impact would depend on the height the home needed to be elevated, home style, and home size. Plans would strive to minimize aesthetic impacts as much as possible, while meeting Corps and FEMA engineering criteria. Landscaping could probably help reduce aesthetic impacts in many cases.

Dikes and floodwalls would also have an adverse aesthetic impact. Oceans views would be obstructed and shoreline access impaired.

For both alternatives, construction activities would have some short term, adverse impacts on the local quality of life. Noise, dust, and truck traffic would disturb the community while work is underway. These impacts would be minimized by time of day and weekend work restrictions, noise limits, dust control measures, and a traffic control plan.

Residents of homes being raised would need to relocate for about two weeks while construction was underway.

5. FEASIBILITY LEVEL ENVIRONMENTAL STUDIES

If the project were to proceed to the Feasibility level an Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) would be prepared to satisfy National Environmental Protection Act (NEPA) requirements. The EA would present a more thorough analysis of environmental impacts associated with the project. If the selected alternative (raising homes) is pursued, the EA would focus largely on potential impacts to cultural resources and aesthetics.

Also during the Feasibility phase, the Corps would obtain a Coastal Zone Consistency Determination from the State of Connecticut. The local sponsor would be required to obtain any other required state or local permits.

6. COORDINATION WITH RESOURCE AND REGULATORY AGENCIES

Coordination letters were sent to the following individuals:

- Mr. John Spencer; CT DEP Bureau of Natural Resources, Hartford, CT.
- Mr. Arthur Rocque, CT DEP Office of Long Island Sound Programs, Hartford, CT.
- Ms. Nancy Murray; CT DEP Natural Diversity Data Base, Hartford CT.
- Mr. Gordon E. Beckett; U.S. Fish and Wildlife Service, Concord, NH.
- Mr. Douglas Thompson; US EPA Region I Wetlands Protection Section, Boston, MA.
- Mr. Christopher Mantzaris; NOAA Fisheries Habitat Conservation Office, Glouchester, MA.
- Mr. John W. Shannahan; Office of the State Historic Preservation Officer for Connecticut, Hartford, CT.

7. CORRESPONDENCE RECEIVED

- 27 May 1994 Letter from Dawn Maddox, Connecticut Historical Commission.

- 12 July 1994 Letter from Mike Ludwig, NOAA Fisheries Habitat and Protected Resources Division.

- 2 August 1994 Letter from Gordon E. Beckett, Fish and Wildlife Service, New England Field Offices.

8. REFERENCES

Greenwich Historical Society. 1990. Greenwich: An Illustrated History. Town of Greenwich Historical Society and Greenwich Time, Greenwich, CT.

Mead, Spenser P. 1979. Ye Historie of Ye Town of Greenwich. Reprinted by Harbor Hill Books, Harrison, NY. Originally published in 1911 by the Knickerbocker Press, NY.

Zeranski, Joe. 1994. (Greenwich Shellfish Warden) 25 July telephone conversation.

APPENDIX D

CENED-PL-P (1105-2-100) 28 February 1995

MEMORANDUM FOR Commander, USACE (CECW-P), 20 Massachusetts Avenue, N.W., Washington, D.C. 20314-1000

SUBJECT: Reconnaissance Report, Old Greenwich, Greenwich, Connecticut (4th Congressional District) CWIS# 86289

1. Under authority contained in Section 103 of the 1962 River and Harbor Act, as amended, a reconnaissance level study of coastal flood damage reduction in the Old Greenwich section of Greenwich, Connecticut has been completed. We have concluded that there is sufficient economic justification to evaluate raising 124 houses above the 100 year flood level in Old Greenwich.

2. The town officials and Old Greenwich residents were informed of the study results and recommendations. However, the town has decided to further review their participation in a cost shared feasibility study. This review is expected to be completed in late 1995. Therefore, further Corps of Engineers study in this area was terminated.

3. A letter of our decision was forwarded to the town and Connecticut DEP on 14 February 1995. Enclosed is a copy of the letter for your information.

Enclosure

EARLE C. RICHARDSON
COL, EN
Commanding

CF: CECW-PE

cf:
Mr. Swaine, 114S
Mr. Pronovost, 114N
Ms. Chu, 114S
Plng. Dir. Files
Prog. Office, 113S
PDB Files, 114S
Reading File

February 14, 1995

Planning Directorate
Coastal Development Branch

Mr. John B. Margenot, Jr.
First Selectman
Town of Greenwich
Office of First Selectmen
101 Field Point Road
Greenwich, Connecticut 06836-2540

Dear Mr. Margenot:

I am writing in regard to our reconnaissance study on shore protection and flood damage reduction at Old Greenwich, Connecticut. Members of my staff met to discuss study findings with town officials and the public at a meeting held November 9, 1994.

I understand the town has decided to further review participation in a cost shared feasibility study. This review is expected to be completed later in 1995. Since the draft report of the study was completed last August, we must at this time conclude our study efforts at the reconnaissance phase. If future conditions warrant a further review, you may request that we reconsider the project at that time.

If you require additional information, Mr. Paul E. Pronovost can be reached at (617) 647-8511.

Sincerely,

Earle C. Richardson
Colonel, Corps of Engineers
Division Engineer

Copy Furnished:
Mr. Charles Berger
Connecticut Department of
Environmental Protection
Inland Water Resources Division
79 Elm Street
Hartford, Connecticut 06106-5127

cc:
Mr. Pronovost
Plng Dir Files/114N(margenot)

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Field Offices
22 Bridge Street, Unit #1
Concord, New Hampshire 03301-4986

August 2, 1994

Joseph Ignazio
Planning Directorate
Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

ATTN: Impact Analysis Division

Dear Mr. Ignazio:

This responds to your letter dated June 30, 1994 requesting information on the presence of Federally listed and proposed endangered or threatened species in relation to the proposed Section 103 shoreline protection in Greenwich, Connecticut.

Based on information currently available to us, no Federally listed or proposed threatened and endangered species under the jurisdiction of the U.S. Fish and Wildlife Service are known to occur in the project area, with the exception of occasional transient endangered bald eagles (*Haliaeetus leucocephalus*) or peregrine falcons (*Falco peregrinus anatum*). However, we suggest that you contact Nancy Murray, Connecticut Natural Diversity Data Base, 79 Elm St., Store Level, Hartford, CT 06106, 203-566-3540 for information on state listed species that may be present.

Preparation of a Biological Assessment or further consultation with us under Section 7 of the Endangered Species Act is not required. Should project plans change, or additional information on listed or proposed species becomes available, this determination may be reconsidered. This response relates only to endangered species under our jurisdiction. It does not address other legislation or our responsibilities under the Fish and Wildlife Coordination Act and the Federal Power Act.

Thank you for your cooperation and please contact Susi von Oettingen of this office at (603) 225-1411 if we can be of further assistance.

Sincerely yours,

Kenneth C Carr

for Gordon E. Beckett
Supervisor
New England Field Offices

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Habitat & Protected
Resources Division
212 Rogers Avenue
Milford, Connecticut 06460-6499

July 12, 1994

Mr. Joseph L. Ignazio
Director of Planning
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Ignazio:

We have reviewed the June 30, 1994 request for information regarding the proposed Section 103, shoreline protection project reconnaissance study for Old Greenwich, Connecticut. As the study will focus on the effects of raising approximately 124 existing residential structures at or below 13 feet N.G.V.D., we cannot identify any potential for impacts to aquatic resources, and have no comment regarding the proposed study.

Should you wish to discuss this matter further, please contact me at the letterhead address or at (203) 783-4228.

Sincerely,

Michael Ludwig
Fishery Biologist

cc:
CT DEP - OLISP
CT DEP - Marine Fish.
EPA - Reg. I
F&WS - RI

STATE OF CONNECTICUT

STATE BOARD OF EDUCATION

CONNECTICUT HISTORICAL COMMISSION

May 27, 1994

Mr. Joseph L. Ignazio
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Subject: Shore and Beach Protection
Greenwich, CT

Dear Mr. Ignazio:

The State Historic Preservation Office understands that the Corps of Engineers is preparing a Section 103 reconnaissance report concerning the above-named project. This office notes that several archaeological reconnaissance surveys have been undertaken in the Town of Greenwich pursuant to local subdivision regulations. Further, the Town of Greenwich, in coordination with our office, has undertaken an extensive identification of its historic and architectural resources. The pertinent citations to these studies which are on file at the Special Collections Department in the Homer Babbidge Library at the University of Connecticut (Storrs) have been enclosed for your information.

This office encourages the Corps of Engineers to consult this extensive cultural resource data as an integral component of its Section 103 investigations. If this project proceeds to a further planning stage, we look forward to working with the Corps of Engineers in the professional management of Connecticut's cultural heritage.

For further information please consult Dr. David A. Poirier, Staff Archaeologist.

Sincerely,

Dawn Maddox

Dawn Maddox
Deputy State Historic
Preservation Officer

DAP

Enclosure

TOWN OF
GREENWICH

Office of First Selectman (203) 622-7710 FAX (203) 622-3767
Town Hall • 101 Field Point Road • Greenwich, CT 06836-2540

John B. Margenot, Jr.
First Selectman

May 19, 1993

Mr. Joseph L. Ignazio, Director of Planning
U. S. Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, MA 02254

Re: Townwide - Tidal Flooding Abatement, Town Project No. 93-18

Dear Mr. Ignazio:

It has been brought to our attention, by the State of Connecticut Department of Environmental Protection, that the U. S. Army Corps of Engineers has grant programs to mitigate property damage caused by coastal flooding. On December 11-13, 1992, the Old Greenwich section of Greenwich experienced heavy damage due to a severe winter storm.

Would you, therefore, kindly evaluate the possibility of the U. S. Army Corps of Engineers participating in a program to reduce losses from future natural disasters. If you need additional information concerning this request, please contact Bob Kendra, our Chief Engineer, at (203) 622-7767.

Thank you for your consideration.

Very truly yours,

John B. Margenot, Jr.
First Selectman

CC: M. F. Roddy, Commissioner of Public Works
R. C. Kalm, Deputy Commissioner of Public Works
R. J. Kendra, Chief Engineer